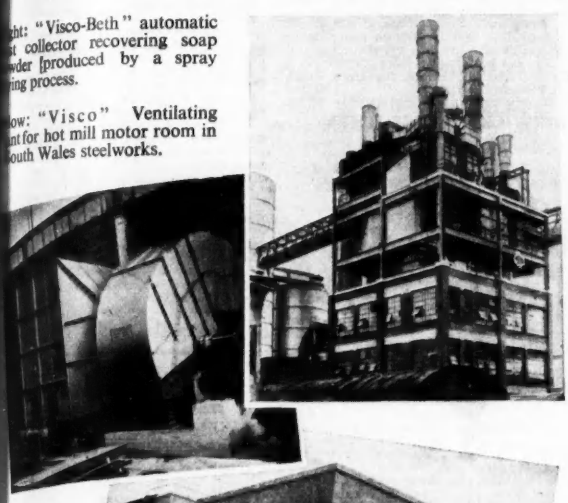
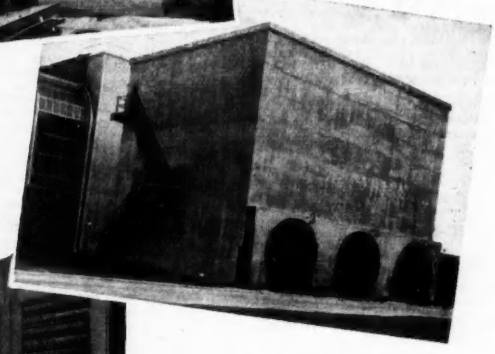
VISCO

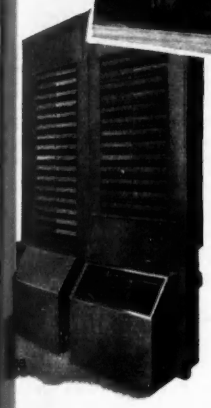
Products in Modern Industry

ght: "Visco-Beth" automatic st collector recovering soap wder produced by a spray ing process.

ow: "Visco" Ventilating nt for hot mill motor room in outh Wales steelworks.







Above: "Visco" ferro-concrete water cooler 300,000 g.p.h. capacity, at the Abbey Works of the Steel Company of Wales.

Left: Two of eighteen sections of 'Reciprojet' self-cleaning air filter 80,000 c.f.m. for use in heavily dust laden atmospheres.

For over thirty years, we have been designing, manufacturing and installing equipment for almost every industry:—Air Filters of all sizes—static and self-cleaning types; Water Coolers in steel, timber, or ferro-concrete; Oil Coolers; Dust Collecting Equipment including "Visco-Beth" automatic dust collectors, unit dust collectors, and high efficiency Cyclones; Air Conditioning Plant for factories, steelworks, etc. Typical examples are shown above.

Our technical staff is at your service for suggestions, specifications and quotations.

VISCO
ENGINEERING CO LTD
STAFFORD ROAD, CROYDON.

Telegrams - - - "Curtmit, Croydon."
Telephone - - Croydon 4181-4 & 2471

THE ENGINEER

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NOTICE TO READERS
All letters intended for insertion in 'The Engineer' or containing questions should be accompanied by the name and address of the writer, not necessarily for publication, but as a proof of good faith. No notice whatever can be taken of anonymous communications. No undertaking can be given to return drawings or manuscripts; correspondents are therefore requested to keep copies.

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LINEAGE RATE (Under 1 inch):—2s. 6d. per line of 6 words. Minimum 10s.

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WORDING OF ADVERTISEMENTS: Approximately the first 25 letters of each advertisement are set in heavy type. Advertisers are therefore advised to begin their advertisements with the words they want emphasized.

Advertisements received by Mid-day Tuesday will appear in the issue of Friday the same week. Orders must be accompanied by a remittance.

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PUBLIC APPOINTMENTS

BOROUGH POLYTECHNIC
BOROUGH ROAD, S.E.1

DEPARTMENT OF MECHANICAL ENGINEERING

LECTURER IN PRODUCTION ENGINEERING

The Governors invite applications for the post of LECTURER IN PRODUCTION ENGINEERING on the staff of the Department of Mechanical Engineering. Candidates should possess a Degree in Mechanical Engineering or an equivalent qualification, and have had some industrial and teaching experience. The Lecturer appointed will be required to teach production engineering subjects up to a standard of the City and Guilds of London Institute Final Examination in Machine Shop Engineering and of the Higher National Certificate in Production Engineering, together with some post-National Certificate courses in Productivity. He will also be responsible for the care and equipment of some of the workshops of the Department.

The salary payable will be in accordance with the scale for Lecturers as provided by the Burnham (Further Education) Report, 1954.

Further particulars and forms of application may be obtained from the undersigned.

DOUGLAS H. INGALL,
Principal.
E6057

SOUTH SHIELDS EDUCATION AUTHORITY

MARINE AND TECHNICAL COLLEGE

Principal :
J. HARGREAVES, M.A., Ph.D. (Cantab)

DEPARTMENT OF MARINE AND MECHANICAL ENGINEERING

ASSISTANT LECTURER

Applications are invited, for duty from January, 1955, of an ASSISTANT LECTURER in the Department of Marine and Mechanical Engineering. Candidates should hold a Degree in Engineering or equivalent qualification, and should have had adequate industrial experience. Seagoing experience would be an advantage. The salary of the post will be in accordance with the Burnham Scale for Grade II Assistants, viz., £525–£25–£820, plus Degree and training allowances in appropriate cases. The initial salary will depend on previous industrial and teaching service. Further particulars and an application form may be obtained from the undersigned, Education Office, Westoe Village, South Shields. Completed applications should be sent to the Principal not later than the 23rd October, 1954.

A. J. W. JEFFERY,
Director of Education.
E6050

THE COLLEGE OF AERONAUTICS

DEPARTMENT OF AIRCRAFT PROPULSION

LECTURER

Applications are invited for the post of LECTURER in the Department of Aircraft Propulsion. Candidates should have advanced knowledge of some branch of thermodynamics or gas dynamics, and of the theory and performance of propulsion units, and some practical experience of one or more modern propulsion systems. They should possess a Degree and/or other recognised professional qualification. Salary within range £600–£1000 per annum, depending upon qualifications and experience, with superannuation under F.S.S.U., and family allowance. A small house on the College estate may be made available.—Applications, giving full details of qualifications, &c., and quoting the names of three referees, should be addressed to the Recorder, The College of Aeronautics, Cranfield, Bletchley, Bucks. Further particulars available. Closing date for applications 12th November, 1954. E6011

WAR OFFICE

ARMY APPRENTICES SCHOOL

INSTRUCTORS

War Office requires at Army Apprentices School, Chepstow, Mon, (a) INSTRUCTOR III (FITTER) (Order No. Chepstow 402), able to teach engine fitting, I.C. and pumps ; (b) INSTRUCTOR III (TELECOMMUNICATIONS) (Order No. Chepstow 152), with sound knowledge of either electricity A.C. and D.C., predictors, power and associated equipment, or up to advanced A.C., able to learn fire control equipment. Candidates for both posts should be fully trained with at least five years' practical experience in fully skilled work ; able to teach, supervise and control trainees. Preference given to holders of O.N.C. or equivalent qualifications. Salary £550 (aged 28) to £640.—Apply to any Employment Exchange, quoting the appropriate Order No.
E6012

LONDON COUNTY COUNCIL

CIVIL ENGINEERS, CIVIL ENGINEERING ASSISTANTS & DRAWING-OFFICE STAFF

CIVIL ENGINEERS, CIVIL ENGINEERING ASSISTANTS and DRAWING-OFFICE STAFF for design of large civil engineering works in connection with main drainage and sewage purification. Salaries within range £300–£739—Application form from Chief Engineer (54/37), London County Council, County Hall, S.E.1, returnable within the next fourteen days. (940) E5265

SURREY EDUCATION COMMITTEE

REDHILL TECHNICAL COLLEGE,
REDSTONE HILL, REDHILL

ENGINEERING COURSES

ASSISTANT LECTURERS

Required, for January, 1955, two ASSISTANT LECTURERS. Both posts are, at present, classified as Grade A, but for either post a suitably qualified man may be appointed as a Grade B Assistant. Candidates should hold a University Degree in Engineering or equivalent qualification ; good industrial training and experience will be an added value. For one of the posts the candidate appointed will be required to teach electrical subjects. Both teachers are needed for the courses leading to Ordinary National Certificate in Mechanical and Electrical Engineering and for City and Guilds courses. Salary : Grade A, £450 by £18 to £725 p.a. Grade B, £525 by £25 to £820 p.a.

Further particulars and forms of application obtainable from the Principal. Completed applications to be returned by 23rd October. E6054

MID-ESSEX TECHNICAL COLLEGE AND SCHOOL OF ART
MARKET ROAD, CHELMSFORD

Principal : C. E. PRESTON, M.B.E., M.Eng., M.I.E.E., M.I.Mech.E.

HEAD OF ENGINEERING DEPARTMENT

Applications invited for post of HEAD OF ENGINEERING DEPARTMENT (Burnham Report Grade III). Salary, £1215 by £25 to £1365 (man). Applicants should possess a good Engineering Degree and had suitable industrial teaching and administrative experience. Further particulars and application form obtainable from the General Education Officer, County Offices, Chelmsford (stamped, addressed foolscap envelope) and returnable by 25th October, 1954. E5942

DUNDEE TECHNICAL COLLEGE

MECHANICAL ENGINEERING DEPARTMENT

LECTURER IN CIVIL ENGINEERING

Applications are invited for the post of LECTURER IN CIVIL ENGINEERING.

Applicants should possess a good Honours Degree and be prepared to undertake research work in Hydraulics. The salary scale is £690 by £30 to £990, but placing may be given to a candidate with suitable experience. Application forms may be obtained from the Clerk and Treasurer, Institute of Art and Technology, 40, Bell Street, Dundee, and should be returned within two weeks from the appearance of this advertisement. E5972

EAST HAM COUNTY BOROUGH

EAST HAM TECHNICAL COLLEGE

ASSISTANT, GRADE A

ASSISTANT, Grade A, required for mechanical engineering subjects to second-year National Certificate standard. Ability to teach sheet metal work or workshop engineering an advantage.

Salary (Burnham scale), £486–£773 per annum, plus additions for approved training and qualifications. Increments allowed for industrial experience.

Application forms (returnable as soon as possible) from Chief Education Officer, Town Hall Annexe, Barking Road, London, E.6. E6060

HAMMERSMITH HOSPITAL AND POSTGRADUATE MEDICAL SCHOOL

DU CANE ROAD, LONDON, W.12

ASSISTANT ENGINEER-IN-CHARGE

ASSISTANT ENGINEER-IN-CHARGE required. Good technical qualifications and experience essential. Salary scale £450–£525 p.a., plus £20/£30 London Weighting. Housing accommodation may be available. Details from Chief Engineer. E5960

NORTH THAMES GAS BOARD

CHIEF ENGINEER'S DRAWING-OFFICE

SENIOR DRAUGHTSMEN

The following SENIOR DRAUGHTSMEN are required in the Chief Engineer's Drawing-Office at Westminster, S.W.1 :—

(i) For the design and layout of general process plant and all associated structural steelwork.

(ii) For the design of materials handling plant and the detailing of associated steelwork.

Candidates should preferably be Corporate Members of the Institutions of Civil, Structural or Mechanical Engineers. Starting salaries within the range £745 to £895 per annum, according to age, qualifications and experience. The successful candidates will be required to join the staff pension scheme.

Applications, giving age and full particulars, should be sent to the Staff Controller, North Thames Gas Board, 30, Kensington Church Street, London, W.8, quoting reference 666/191. E6025

DORSET COUNTY EDUCATION COMMITTEE

SOUTH DORSET TECHNICAL COLLEGE

ASSISTANT

Applications are invited for the post of ASSISTANT to teach Machine Shop Engineering (Theory and Practice) and to assist with Drawing, Science and Mathematics in the Engineering Department. Good teaching and practical experience necessary.

Salary : Burnham Technical Scale, Grade A.

Further particulars and application forms, to be returned within 14 days from the appearance of this advertisement, can be obtained from the Principal, South Dorset Technical College, Newstead Road, Weymouth, Dorset. E5975

WARWICKSHIRE COUNTY COUNCIL

ARCHITECT'S DEPARTMENT

APPOINTMENTS

Applications are invited for the following appointments :—

(1) ASSISTANT HEATING ENGINEER, with extensive experience in the design of heating, hot and cold water supplies and allied services, the preparation of specifications, bills of quantities and estimates, and the running of contracts. Membership of the Institution of Heating and Ventilating Engineers required. Salary, £695, rising to a maximum of £810 per annum.

(2) HEATING ENGINEERING ASSISTANT, experienced in the preparation of schemes for heating and hot water and specifications for such work with limited supervision. Preference given to a Graduate or Associate of the Institution of Heating and Ventilating Engineers. Salary, £620, rising to a maximum of £760 per annum.

The appointments are on the established staff and will be subject to the provisions of the Local Government Superannuation Acts, 1937–53. The successful applicants will be required to pass a medical examination.

Applications are to be made on a form which can be obtained from G. R. Barnsley, F.R.I.B.A., County Architect, Shire Hall, Warwick.

L. EDGAR STEPHENS,
Clerk of the Council.

Shire Hall,
Warwick,
9th October, 1954. E6053

NATIONAL COAL BOARD

ENGINEERING BRANCH OF PRODUCTION DEPARTMENT

ASSISTANT CIVIL ENGINEER

National Coal Board invite applications for the superannuable appointment of an ASSISTANT CIVIL ENGINEER in the Engineering Branch of Production Department in London.

Applicants should have had experience in a reinforced concrete specialist's design office. They should also be pursuing a course of study for a recognised professional qualification.

The appointment will, in the first place, be in London, but good opportunities for obtaining site experience occur from time to time and preference will be given to candidates who express their willingness to be considered for these field appointments as they arise.

The salary, depending on qualifications and experience, will be in the range of £450 to £750 per annum.

Write, giving full particulars (in chronological order) of age, education, qualifications and experience (with dates), to National Coal Board, Establishments (Personnel), Hobart House, Grosvenor Place, London, S.W.1, marking envelope TT/853. Original testimonials should not be forwarded. Closing date 3rd November, 1954. E5980

BRITISH ELECTRICITY AUTHORITY

LONDON DIVISION

CIVIL ENGINEERS (JUNIOR)

CIVIL ENGINEERS (JUNIOR) required for training in general civil engineering work connected with the construction and maintenance of power stations. Applicants should have Higher National Certificate in Civil and/or Structural Engineering, with good knowledge of theory of structures and applied mechanics. Salary in accordance with N.J.B. Agreement, Schedule C, Class AX/EX, Grade 9, within range £415/£618 9s. p.a., including London allowance.—Applications, quoting Vacancy Number 54/857, may be made on form obtainable from Divisional Secretary, British Electricity Authority, London Division, P.O. Box 136, Generation House, Great Portland Street, W.1. E5995

COUNTY BOROUGH OF EAST HAM

APPOINTMENTS

TEMPORARY ESTIMATOR, Grade V, £620–£670 ; SENIOR ENGINEERING ASSISTANT, Grade VI, £695–£760 ; ARCHITECTURAL ASSISTANT, Grade V, £620–£670.

London weighting is paid in addition. Salary in excess of the minima may be paid according to qualifications and experience.

Subsistence allowances may be granted over a reasonable period to persons appointed if unable to obtain suitable housing accommodation, necessitating the maintenance of two homes.

Further details and application forms returnable by 29th October, 1954, from the Town Clerk, Town Hall, East Ham, E.6. E5987

PUBLIC APPOINTMENTS

AUSTRALIA

QUEENSLAND GOVERNMENT RAILWAYS

VACANCIES—DESIGNING CIVIL ENGINEERS

Applications will be received by the undersigned until 15th November, 1954, from persons desiring to join the service of the Commissioner for Railways, Brisbane, Queensland, Australia, as DESIGNING CIVIL ENGINEER, Chief Engineer's Branch (Bridges) required).

Present salary range is £1049 10s. minimum to £1184 10s. maximum per annum (Australian currency).

Applicants must hold Degree in Civil Engineering from a recognised University or equivalent qualification such as Corporate Membership of the Institution of Civil Engineers.

They must be capable of making complete calculations, design and working drawings for civil engineering structures, including railway and road bridges of all types, retaining walls, culverts, drainage works, and water supply schemes, and must have had not less than two (2) years' experience in graduation in designs of this type, including reinforced concrete designs.

Applicants should state age, qualifications, experience, and attach copies of references as to character and ability.

Appointees will be entitled to the usual free privilege ticket concessions applicable to officers of the Queensland Railways.

D. J. MUIR,
Agent-General for Queensland,
409–410, The Strand,
London.

STAFFORDSHIRE POTTERIES WATER BOARD

APPOINTMENT OF SENIOR ENGINEERING ASSISTANT

Applications are invited for the above appointment at a salary in accordance with Grade VIII (£785 by £25 to £860 p.a.)

Applicants must be Corporate Members of the Institution of Civil Engineers and have had experience in the design and construction of waterworks. Board have considerable major works in hand including reservoirs and pumping schemes.

A modern house in a pleasant residential district available for the successful candidate on appointment of tenancy.

The appointment is subject to the provisions of the National Scheme of Conditions of Service, the provisions of the Local Government Superannuation Act, 1937 ; to termination by one month's notice on either side ; and to the successful candidate passing a medical examination.

Applications, stating age, full details of professional qualifications, present and previous appointments and experience, together with copies of recent testimonials or names of two persons to whom reference can be made, should be forwarded to the undersigned not later than Friday, 22nd October, 1954, endorsing the envelope "Senior Engineering Assistant."

C. V. BROWN, M.I.C.E., M.I.Mech.E., M.I.E.E.,
Engineer and Manager and Clerk to the Board.
Staffordshire Potteries Water Board,
Albion Street,
Hanley,
Stoke-on-Trent.
4th October, 1954.

UNITED KINGDOM ATOMIC ENERGY AUTHORITY

RISLEY

CHEMISTS OR ENGINEERS

CHEMISTS or ENGINEERS required by United Kingdom Atomic Energy Authority at Risley, to work in headquarters section whose function is the co-ordination and control of a group of factories. Duties include methods studies, supply of experimental plant and equipment, and control of tests. Qualifications : Honours Degree in Science or Engineering or Corporate Membership of a recognised professional institution, with a variety of chemical or engineering experience in industry or a research establishment. Organisation and methods experience preferable to experience of plant operations or experimental work. Salary according to age and experience, within the ranges £[illegible] to £960 and £960 to £1240. The successful candidates will later be required to join the Authority's contributory pension scheme and salaries will be increased to cover the contributions. Applications to United Kingdom Atomic Energy Authority, Industrial Group Headquarters, P.O. Box 6, Risley, Warrington, quoting 688.

MINISTRY OF SUPPLY

DRAUGHTSMEN

DRAUGHTSMEN required by Ministry of Supply at various locations, with experience in any of the following classes of work : chemical plant, lighting, mech., automobile, precision instruments, optical, radar, electrical, electronics, structural, press tool, jig and tool. At least 3 years' workshop experience and O.N.C. or equivalent. Starting pay [illegible] £380 (age 20), £550 (age 28), rising to £640 (age 30) ; rates higher. Paid sick leave, 20 days' annual holiday, plus public holidays ; 44-hour week (generally 5-day) including meal breaks. Premium rates for overtime. Appointments unestablished, but opportunities to compete for pensionable posts. Prospects of promotion to Leading Draughtsman, £[illegible] (prov.), thence to Senior Draughtsman, £[illegible] (prov.), and Chief Draughtsman, £[illegible] (prov.).—Write, stating age, training, and experience, to Ministry of Supply, Est. 3[illegible], 519, Carlton Hotel, Haymarket, London, S.W.1.

THE ENGINEER

OCTOBER 15, 1954

Development of Electronics Industry in Scotland

LAST Monday H.R.H. The Duke of Edinburgh, officially opened a new electronics laboratory at the Edinburgh factory of Ferranti, Ltd. Although the laboratory will serve as the main centre of the company's own research effort, it is part of a scheme designed to introduce the electronics industry to Scotland. This scheme was elaborated in an address at the ceremony by Lord Bilsland, who is president of the Scottish Council (Development and Industry). He said that the development of many of the newer industries between the wars had tended to pass Scotland by, and the electronics industry had threatened to follow the same path. To arrest this tendency the Scottish Council instituted discussions with the Ministry of Supply, the Admiralty and Scottish firms, as a result of which Ferranti, Ltd., agreed to act as a channel through which Government electronic contracts might flow to other Scottish firms undertaking this work for the first time. Ferranti, Ltd., also offered to take engineers from other Scottish firms into its laboratory to learn the new techniques, so that the laboratory would act as a "seed bed" from which young electronic teams could be transplanted to other firms. The Ministry of Supply and the Admiralty agreed to use this scheme in order to direct a larger flow of electronic work to Scotland, and the Ministry agreed to provide the new laboratory to accommodate not only Ferranti, Ltd.'s own design staff, but also up to forty engineers from other firms. The new building which was completely occupied with all its complex services installed twenty-one months after work was commenced, has a total floor area of 55,000 square feet. It has a reinforced concrete frame and the columns and beams are exposed on the elevations as an architectural feature. There are twenty-four project laboratories arranged on three floors. Many distinguished visitors, including the Minister of Supply, Mr. Duncan Sandys, were the guests of the Scottish Council at luncheon. Speaking after the luncheon, Mr. Sandys stressed the untiring efforts and even the pressure which Lord Bilsland had exercised in promoting the post-war development of industry in Scotland.

Railway Accidents in 1953

YESTERDAY there was published by H.M. Stationery Office the report made to the Minister of Transport by Lieut.-Colonel G. R. S. Wilson, chief inspecting officer of railways, on the accidents which occurred during 1953 on the railways of Great Britain. It records these accidents under three classifications, namely, train accidents, that is accidents to trains and rolling stock on a passenger railway, and failures of rolling stock, track and structures; movement accidents, which are those concerned with the movement of railway vehicles exclusive of train accidents; and non-movement accidents, which are those on railway premises not connected with the movement of any railway vehicles. The report shows that during the year there were 1123 train accidents, or 120 fewer than in the preceding year, the casualties numbering forty-eight killed and 608 injured. There was a substantial reduction, compared with earlier years, in the number of failures of permanent way, structures and rolling stock. In movement accidents last year, 258 people were killed and 6857 were injured, and through non-movement accidents there were forty-one fatalities and 17,663 people injured. In some general comments, Colonel Wilson says that with one passenger fatality in 71,000,000 passenger journeys and one serious casualty in 27,000,000 journeys there was nothing that was discouraging in the record of safety on the railways in 1953, though it fell short of the highest standards of previous years. The renewal programme during the year was more than sufficient to keep pace with wear and tear, and the better average condition of track, rolling stock and other equipment was reflected in the decline in the totals of train accidents and failures reported. The report adds that the number of accidents last year attributable directly to the failure of operating staff was practically the same as in 1952, but as in other years "there was a high proportion of minor cases." All will recognise, however, Colonel Wilson remarks, that there is still a need for improvement in this direction, and he expresses the hope that difficulties in recruiting and retaining good men for the operating and maintenance staff will soon be overcome.

Institution of Production Engineers

THE annual dinner of the Institution of Production Engineers was held on Friday last at the Dorchester Hotel, in London, under the chairmanship of Sir Walter Puckey, president of the Institution. The guest of honour, Lieut.-General Sir Ronald Weeks, K.C.B., was unfortunately prevented by illness from attending and his prepared speech was read by Lord Sempill. In his speech, Sir Ronald recalled a remark he had made six years previously that "as a nation which had specialised in manufacture and was dependent on world markets, this country could not expect stability and repose." He said that although confidence in our industrial programme was high, we were not improving our productivity quickly enough. For the last five years, the annual improvement had been 3 per cent, compared with 3½ per cent in the U.S.A. and 16 per cent in Germany, though in the case of Germany a fairer comparison would be with the years 1952 and 1953, giving a 4½ per cent improvement. In face of this our gold and dollar reserves, though improved, were not adequate; we could not decrease imports further without lowering the standard of living; our internal and external debt was increasing; overseas competition was intensified, and the wages spiral continued to rise. Dealing with the many factors which had an influence on productivity, Sir Ronald said that in his capacity as chairman of the National Advisory Council for Technical Education for Industry and Commerce, he wished to talk more fully on the subject of education for research and technology. New post-graduate courses had been and were being developed by the Universities and additional facilities were being considered by the Government. The National Advisory Council had since 1950 proposed a Royal College of Technology and a nationally recognised award for proficiency, together with a national body to moderate the courses and grant the awards. The connection of technical colleges with local authorities and local industries must not be severed, especially where the needs of the part-time student were concerned, but in addition there was the need for a post-graduate establishment which would take the very best qualified people who would be trained scientifically, and also have a period of works training, and turn them into practical high-grade technologists.

Society of Consulting Marine Engineers and Ship Surveyors

ON Friday last the Society of Consulting Marine Engineers and Ship Surveyors held its annual dinner with the president, Mr. Gilbert Knowles, in the chair. In reply to the toast of "The Shipping Industry," proposed by by Mr. Roland Adams, Q.C., Wreck Commissioner, Mr. J. C. Denholm, the president of the Chamber of Shipping, said that in addition to casualties due to tempests, shipping was open to the effects of economic storms, which could, according to the degree of severity, result in the foundering of whole fleets. Such situations had to be countered by the efforts of shipowners, and Mr. Denholm expressed his confidence in the ability of British owners to weather these storms without asking for favours, but provided that they had a fair field. This latter condition, he continued, could not be said to exist when high taxation at home was considered in association with the flag discrimination practised by foreign countries. Among the other problems facing the industry Mr. Denholm mentioned low freight rates in the tramp and tanker sections, increased competition by the Japanese in the liner trade and the greater competition offered by road and rail services and family-manned foreign ships to our coastal shipping. Other adverse factors, of which he said the Society has knowledge, were related to the high and largely unknown new building costs coupled with greatly inflated maintenance charges. The latter item, he commented, not only had a direct influence on running costs but also upon insurance premiums. He felt that all would benefit if the uncertainty regarding the eventual cost of repairs could be removed or at least limited. Mr. Leslie Bowes, the chairman of the Liverpool Steam Ship Owners Association, who proposed the toast to "The Society," also dwelt upon the question of flag discrimination and mentioned several measures adopted by many governments which came within this category. These measures, he continued, if not countered would reduce our volume of shipping, a result which would be detrimental to the State by reducing the industry's contribution to the country's invisible assets. Turning to matters related to the Society, Mr. Bowes commented upon the part played by its members in building and maintaining the British merchant fleet and expressed the hope that the Society would be granted the Royal Charter to which it aspired.

International Internal Combustion Engine Congress

IN our issue of September 24th, we published some particulars about the International Internal Combustion Engine Congress, which is to be held next year at The Hague, and about British participation in that congress. A British national committee has been formed under the chairmanship of Mr. W. K. G. Allen, with Mr. Malcolm Logan as secretary. It has now been stated that the subject matter to be discussed at the congress falls under two main headings, namely, the present-day possibilities of the technique of the diesel engine for railway traction, and the possibilities of the diesel engine for marine and stationary purposes. The actual dates of the congress are from Monday to Thursday, May 23 to 26, 1955, most of the sessions being held in the Kurhaus Hotel, Scheveningen. Arrangements are being made for delegates to the congress to spend the day of Friday, May 27th, in visiting industrial plants in the neighbourhood of The Hague. As far as is known at present, the charges for attending the congress will be approximately £10 a head for delegates and £7 a head for ladies accompanying them. All inquiries from those desirous of attending the congress should be addressed to the Secretary of the National Committee, c/o The British Internal Combustion Engine Manufacturers' Association, 6, Grafton Street, London, W.1.

Skin Plating on Steel Gates

By SERGE LELIAVSKY, Ph.D., M.I.C.E., M.Am.Soc.C.E.

No. II—(*Concluded from page 476, October 8th*)

There seems to be no reason why the thickness of skin plating on hydraulic gates should be correlated with the span of the gate. The author shows, however, that in practice it does seem to be assumed that a correlation should exist. Various methods of calculating the thickness of skin plating are then considered. But none is found to give results that correlate at all well with practical experience of the failure of such plating. The plating appears capable of carrying far greater loads than the theories would permit. It is therefore suggested that systematically planned full-scale experiments should be carried out under conditions reproducing practical gate design.

Further Developments of the Theory of the Steel Plate

We have, thus far, considered two stages in the development of this theory. First, the earlier period comprising the elementary methods based on the mechanical theory of everyday engineering routine, and secondly, the more advanced theories which take into account the lateral deformation of the metal covered by Poisson's ratio. The third step, which is dealt with below, introduces into the analysis of the plate behaviour the still further factor, in addition to those already considered, of the tensile effect consequent on the elastic deflection. Had the plate been ideally rigid, or had its edges been provided with sliding or roller bearings, this effect could never have developed. However, since the plate is usually much more flexible than a beam of the same span and since its ends are riveted to the beams upon which they rest (while the beams in question possess a certain degree of lateral rigidity, or are prevented from moving transversely by the plates spanning the neighbouring panels), it follows that each plate must start to work as

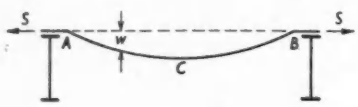


Fig. 6

a chain, creating, consequently, a longitudinal component of the end reaction (see Fig. 6).

In investigating the problem Forchheimer starts[7] with the usual equation of the elastic line framing the law of proportionality between the second derivative of the deflection and the bending moment, viz.

$$\frac{d^2w}{dx^2}=\frac{M_x}{EI(1+\gamma^2)}$$

in which the term $(1+\gamma^2)$ is an approximation to the effect of the lateral restraint discussed in the foregoing paragraph, γ being the reciprocal of Poisson's ratio. The characteristic point of Forchheimer's investigation is that in addition to the usual formula for the bending moment, viz.

$$\frac{pa^2}{8}-\frac{px^2}{2}$$

his new equations include also the bending moment consequent on the longitudinal tensile reaction at the support, i.e. $S\times w$ (see Fig. 6), which, as explained, is due to the deflection of the plate.

The equation for the elastic axis then takes the form

$$\frac{d^2w}{dx^2}=\frac{\frac{pa^2}{8}-\frac{px^2}{2}-Sw}{EI(1+\gamma^2)} \quad . \; . \; . \quad (11)$$

[7] Forchheimer, "Die Berechnung ebener and gekrummter Behälterböden," 1909, page 3.

After integration this equation becomes

$$w=\frac{p}{S\lambda^2}\left[1+\frac{\cosh(\lambda x)}{\cosh(\lambda a/2)}\right]-\frac{p\left(\frac{a^4}{4}-x^2\right)}{2S} \quad . \quad (12)$$

in which λ is the parameter

$$\sqrt{\frac{S}{IE(1+\gamma^2)}}.$$

To find the maximum deflection, we substitute in this equation $x=0$, and thus obtain

$$w_{max}=\frac{p}{S\lambda^2}\left[1-\operatorname{sech}(a\lambda/2)-\frac{\lambda^2a^2}{8}\right].$$

The corresponding value of the maximum bending moment, in the middle of the span, is obviously :

$$M_{max}=\frac{pa^2}{8}-Sw_{max}=\frac{p}{\lambda^2}[1-\operatorname{sech}(a\lambda/2)].$$

It remains now to determine the tensile force S. Since this force is proportional to the width of the plate, it will suffice to consider a unit width of the latter. In order to solve this problem we must find the elongation of the plate, $a'-a$, in which a' is the length of the curve representing the elastic axis (see *ACB* in Fig. 6). Then

$$S=\frac{a'-a}{a}E(1+\gamma^2)h \quad . \; . \quad (13)$$

It is a well-known point of school-room calculus that problems concerning the lengths of analytical curves lead frequently to somewhat involved integrals, e.g. the length of an ellipse was one of the problems which prompted the development of the theory of elliptic integrals with all its far-reaching ramifications. To simplify the calculation Forchheimer introduced in the equation of the elastic axis the usual approximations, permissible when dealing with very flat curves, and thus obtained a solution capable of being transcribed in the following general form :

$$\frac{16h^4E(1+\gamma^2)}{pa^4}=\phi\left(\frac{\lambda a}{2}\right).$$

For the function $\phi(\lambda a/2)$ he gave a table which, to facilitate interpolation, the author converted into a graph (see Fig. 7).[8] For design purposes the calculation is, then, performed as follows :—

(1) According to the conditions of the problem, (i.e. the load, the span and the thickness of the plate), calculate

$$\frac{16h^4E(1+\gamma^2)}{pa^2}=\phi\left(\frac{\lambda a}{2}\right)$$

(2) Then, using the curves in the diagram, Fig. 7, find the corresponding value $\lambda a/2=A$ and calculate therefrom the force S (per unit width of plate) :

$$S=4A^2IE(1+\gamma^2)/a^2.$$

(3) Find the maximum deflection

$$w_{max}=\frac{p}{S\lambda^2}\left[1-a\lambda/2-\frac{\lambda^2a^2}{8}\right]$$

and the maximum bending moment

$$M_{max}=\frac{pa^2}{8}-Sw_{max}.$$

(4) Calculate the maximum stress, i.e. the sum of direct tension due to the force S, viz. S/h, plus the tensile bending stress $6\,M_{max}/h^2$; thus

$$\zeta_{max}=\frac{S}{h}+6M_{max}/h^2 .$$

In the case when the ends of the plate are rigidly fixed (encastrés) at their supports, there will be an additional fixation moment, M_f, to be considered in writing the equation of the elastic axis, namely :

$$\frac{d^2w}{dx^2}=\frac{\frac{pa^2}{8}-\frac{px^2}{2}-Sw+M_f}{EI(1+\gamma^2)} \quad . \; . \quad (14)$$

Integration will then yield

$$w=\frac{pa}{2S\lambda}\coth(\lambda a/2)\times\left[1-\frac{\cosh(\lambda x)}{\cosh(\lambda a/2)}\right]-\frac{p\left(\frac{a^2}{4}-x^2\right)}{2S} \quad . \; . \; . \; . \; . \quad (15)$$

in which λ is the same parameter as in the earlier equations.

[8] Figs. 7 and 8 were first published in the author's discussion of Mr. Ewell's paper mentioned on page 476 *ante*. (See *Trans. Am.Soc.Civ.Eng.*, Vol. 117, 1952, page 902.)

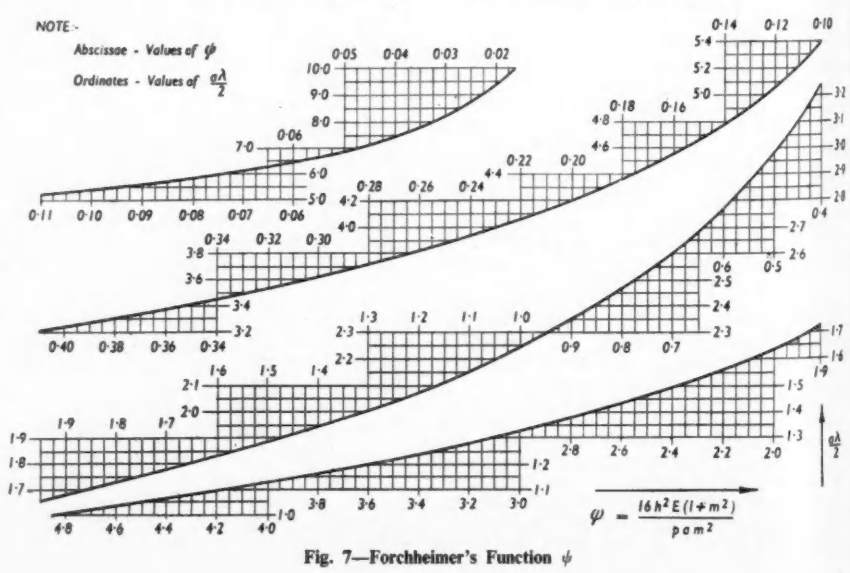


Fig. 7—Forchheimer's Function ψ

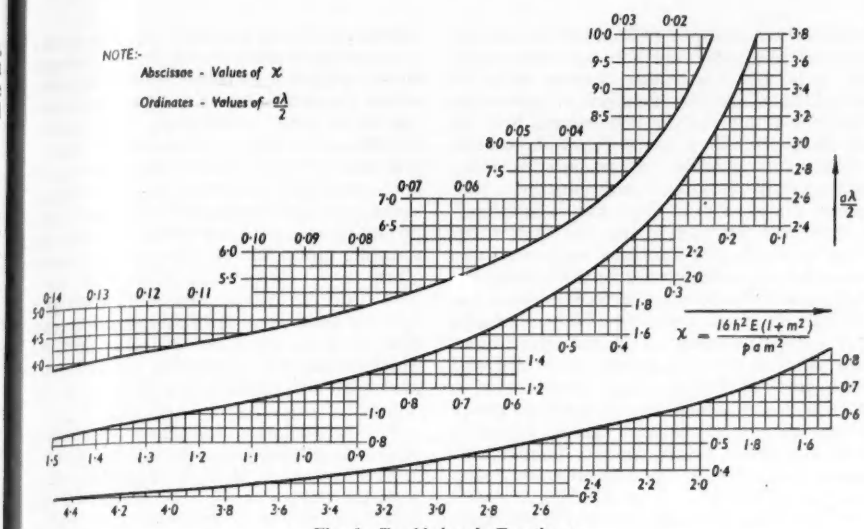


Fig. 8—Forchheimer's Function χ

For $x=0$, viz. in the middle of the plate, the maximum deflection is

$$w_{max}=\frac{pa}{2S\lambda}\coth(\lambda a/2)\times[1-\operatorname{sech}(\lambda a/2)]-\frac{pa^2}{8S} \quad . \quad . \quad . \quad . \quad . \quad (16)$$

For the calculation of the tensile force S, Forchheimer follows in this case the same method as with the simply supported plate. He uses as starting point the difference in the lengths of the plating, before and after its deflection, and in this manner derives the new function which correlates the value of

$$\frac{16h^4E(1+\gamma^2)}{pa^2}=\psi\left(\frac{\lambda a}{2}\right)$$

with $\lambda a/2$.

Forchheimer's table for this function was used by the writer in preparing the diagram Fig. 8. The maximum moment does not occur in this case in the middle of the span, but shifts to the two supports. It is negative and can be calculated from

$$M_f=-\frac{p}{\lambda^2}\left[\frac{a\lambda}{2}\coth(\lambda a/2)-1\right].$$

The sequence of the operations to be performed in applying this theory to practice is the same as for the supported plate, and does not therefore require to be gone into in detail again.

General Conclusions

The diversity of the theoretical methods described in the foregoing pages, as well as their rather involved character, are in a flagrant disaccord with the elementary simplicity of the structural element to which they all refer, i.e. the plate. This fact, alone, suffices to place some doubt on their practical value. Faced with so many theoretical concepts, the designer is at a loss as to which one among them to choose, particularly owing to the scarcity of the available experimental information on the subject. In addition to which, there is also the fact that they all seem to overestimate the required thickness of the plating.

Failures correlated with the main design parameter of the skin plating—that is, the bending stress—are very far from frequent. If, and when, a plating fails, it is most often due to altogether different causes. To give an instance, attention is called to Figs. 9 and 10, reproduced from *Engineering News-Record* for March 21, 1946, page 81. The first one shows the bottom part of the plating of the Bonneville Dam gates, which was torn out during the spring floods of 1945. The damage was obviously due to the negative pressure in the expanding section of the throat (see Fig. 10) formed by the sloping " fair-water " plate on one side, and by the curved surface of the concrete sill, on the other. The mechanical action of this negative pressure is said to have been greatly magnified by the vibration of the gate (the amplitude of which was observed to attain as much as ¼in). The cause of the trouble obviously differs basically from the assumptions of the manifold theories. The plating was not broken or pressed in, as those theories assume, but was bodily torn away from the rest of the metal work. It is therefore obvious that bending stress had no relation with this failure at all. In fact, if bending stress failures of platings in gates do ever actually occur in practice, they must be extremely rare.

It seems possible, therefore, that the bending stress limit which, thus far, has formed the basic parameter of all the relevant theories, may not in Nature be the true criterion at all, or, alternatively, if it is indeed the criterion, then it must greatly exaggerate the danger of failure, when applied in conjunction with the usual standard limits for permissible intensities adopted in other branches of steel design. From the numerous facts of everyday practice tending to confirm the point of this argument, it will suffice to recollect that the plating of the Zifta gates (see Fig. 1) was still capable of withstanding the water pressure, in spite of the fact that its thickness was reduced by rust to almost nothing !

In order, however, to be able to apply this conclusion in practice and thereby achieve material saving in the cost of

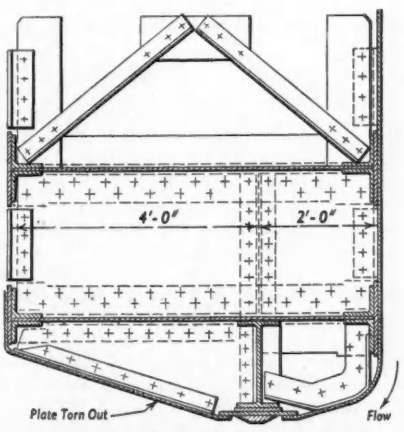


Fig. 9—Bottom part of plating of gates of Bonneville Dam

hydraulic structures, it must first be verified experimentally, under conditions approaching those of actual gates, i.e. the tested plates must be riveted or bolted to structural steelwork, similar to that of the framework of gates. The object of such tests should be

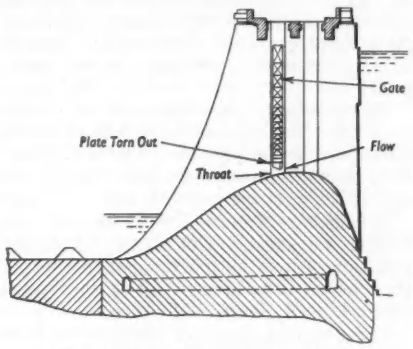


Fig. 10—Flow of water under gates of Bonneville Dam

twofold—to find which, if any, of the existing theories is the true one, and to determine the values of the stress limits or other relevant parameters.

In this connection, it may be of interest to describe the classical experiments of Bach, which were referred to earlier in this article, for they served to establish the design methods commonly applied at present. In the first instance, attention will be called to the fact that these experiments were carried out chiefly in connection with boiler work rather than with gate design. This fact explains why the sizes of the plates were relatively small, e.g. 40cm by 80cm, whilst the pressures experimented with were rather on the high side, attaining 50 atmospheres and even more.

The general arrangement of the testing apparatus used in these tests will be clear from Fig. 11.[9] As seen from this diagram

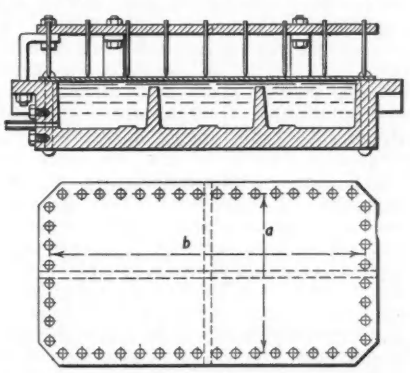


Fig. 11—Arrangement of Bach's testing apparatus

a wrought iron plate was riveted to a cast iron container of appropriate size. Above the plate a number of " needles " were provided for measuring its deflections. Depending on the shape of the tested plate, the container was either square or oblong in plan. To carry out the test the container was connected with a pump and the water pressure applied to the plate was raised gradually to the required intensity.

The results of the following four tests are selected for quotation, as particularly significant in connection with our problem :—

Square Plate.—Sides $a=b=80$cm. Assuming 900 kg per square centimetre as the tensile limit for the material of the plate, Bach calculated the permissible water pressure

[9] See Bach's publications in " Zeitschrift d. Ver. Deutscher Ing.," 1893, page 490, 1906, page 1940, and others. Also see writer's discussion of Mr. Ewell's paper.

within the container to be 0·48 atmospheres. Actually the pressure was raised to 24 atmospheres without failure, or any sign thereof. The thickness of the plate was in this case 0·8cm.

Square Plate.—The same size, but twice as thick. Calculated permissible pressure 1·92 atmospheres. Experimental pressure 20 atmospheres. No sign of failure but test interrupted owing to leaks in the riveted joint.

Rectangular Plate.—Sides a=40cm and b=80cm. Thickness of metal 0·8cm. Calculated permissible pressure 1·2 atmospheres. Experimental pressure 28 atmospheres. No sign or trace of incipient failure.

Rectangular Plate.—The same size, but double thickness. Calculated permissible pressure 4·8 atmospheres. Experimental pressure 34 atmospheres. Test interrupted owing to leaky joint.

These results speak for themselves. Considering that the usual steelwork design incorporates a safety factor of 3 to 4, it is scarcely possible to find reasons for using a factor of 50 for calculating a skin plating. And yet this is what we are currently doing! The disproportion between assumption and test is of so high an order as to suggest that the whole theory may possibly be at fault. It seems also that though Bach's name and theory are quoted by so many authors, few, if any, among them have ever gone into the trouble of studying the original records of his famous experiments; for had these authors been aware of the actual figures they could have scarcely backed the current calculation methods commonly employed in steel gate design.

Without further experimental evidence on the subject it may perhaps be difficult to say for certain what does actually occur; but a tentative explanation may possibly be put forward, by analogy with various other fields of engineering inquiry, that we are faced here with a case of "inelastic bending." The non-linear behaviour of metals beyond the elastic range of stresses is a popular subject of modern progressive research work, particularly in England; for instance, the plastic deformation of plates has already been studied, though from another angle, by Hopkins.[10] From among dozens of other publications on the subject, the paper presented to the American Society of Civil Engineers by Hrennikoff[11] may be mentioned as describing an attempt at a general theory of inelastic bending, capable of being applied to the case in hand. Should, indeed, this method, or as to that any other similar solution, be taken advantage of to solve our problem, Forchheimer's S force, appearing in equations (11) to (16), would have to be recalculated, taking into account the non-linear interdependence between stress and deformation.

It is, however, a matter of considerable doubt whether a solution obtained in this way would carry enough weight to convince the practising engineer and to induce him to alter basically the scantlings of his design; for, in addition to the intricacies inherent in the statical problem of the plate, such, for instance, as the co-existence of two forces S acting at right angles to one another (i.e. in the x and y directions), there would then be other causes of uncertainty also, consequent on the still debatable points of the new inelastic bending theory, e.g. the two elastic limits, the factors affecting stress recession, &c.

There are therefore sufficient reasons to believe that safe but reasonably economical design standards—whether embodied in a basically new elementary theory or transcribed in a scheme of empirical rules—can only be obtained from a comprehensive set of systematically planned full-scale specific experiments carried out under conditions reproducing practical gate design. The writer ventures to suggest that such experiments are essentially an engineer's job rather than that of a physicist or a mathematician. His own personal interest in the matter was prompted by a *mea culpa* feeling about the reconditioning of the gates of Esna Barrage, particularly in regard to the strengthening of the skin plate which he recommended and designed. It formed the main item of a £100,000 job which to his best judgment might have possibly been saved. Notwithstanding which, he would have followed the same route had he been faced to-day with the same problem; for all the available formulæ and methods point in the same direction, and in a work of such importance, involving a wide scope of public interest, the intuitive feeling of the designer, however strong, does not suffice for departing drastically from an established theory, consecrated by usage. Such is, indeed, the case with hundreds (if not thousands) of gates designed annually, all over the world.

If the existing routine is to be broken once and for all, the point of the new argument must be demonstrated in such a manner as to leave no doubt possible in the mind of the designer as to the practical value of the suggested alteration. The experiment must therefore be capable of easy interpretation in terms acceptable to wide circles of engineers, rather than being a purely scientific research scheme, however brilliant and to the point. It goes, of course, without saying that the proposed experimental investigation must be both scientifically correct and scientifically significant, but its appeal must be focused primarily on the practising engineer, the scientific research man coming in the second place.

In order to achieve this result the experiments should be designed, carried out and interpreted by engineers and published in a widely circulated engineering magazine, preferably by an authoritative society or institution.

Another technical point substantiating the object and necessity of such experiments is that in the region of, and beyond, the elastic limit the behaviour of modern steel plating differs essentially from that of the plates experimented upon by Bach. In fact, when his tests were carried out at the end of the last century, the plates he used were made of wrought iron, which explains the low stress limit, viz. 900 kg per square centimetre, he adopted in his calculations.

The programme of the new tests must therefore include, among others, comparative experiments with more or less ductile materials. It might indeed be found that in this particular type of work ductility is a more important consideration than ultimate resistance.[12]

[10] H. G. Hopkins, "Plastic Deformation of Rectangular Plates Under Direct Loads," "Engineering Structures," Academic Press, New York.

[11] A. Hrennikoff, "Theory of Inelastic Bending with Reference to Limit Design," *Trans. A.S.C.E.*, Vol. 113, page 213.

[12] "Importance of the Ductility of Steel for Calculating and Dimensioning Steel Structural Work, Especially when Statically Indeterminate," Rept. International Assn. for Bridge and Structural Eng., Berlin, 1936.

Power: Past and Future

By J. ECCLES, C.B.E., B.Sc., M.I.C.E., M.I.Mech.E.*

In his inaugural address as president of the Institution of Electrical Engineers, Mr. Eccles reviewed the development of power over the ages beginning 300 million years ago, when the coal and oil measures were laid down. After pointing out that these reserves of fuel are running out he reviewed other sources of power, including nuclear power, and referred to estimates of the availability of uranium ores, reserves of which may be sufficient to meet man's power needs for some 8500 years.

SOME geologists compute the age of the earth to be about 3000 million years. Nine-tenths of that period passed without any event of significance to power engineers until about 300 million years ago, in circumstances which we can only conjecture, there seems to have occurred upon this planet a condition, or series of conditions, conducive to luscious vegetable growth over large tracts of its swampy surface. Vegetation grew, decayed, was reborn, and decayed, repeating its life cycle for perhaps tens of millions of years, until there was built up stratum upon stratum of hydro-carbonaceous matter.

Times changed, the climate altered, there were violent internal explosions with consequent disturbance of the earth's crust, dry land became the sea-bed, the valleys were exalted, the mountains were brought low, there were long periods of snow and ice, and never again have there been repeated in nature conditions so conducive to an accumulation of her precious hydro-carbon store. To this event, or series of events, we owe the coal measures and the oil wells which to-day provide over 85 per cent of the world's fuel. This garnering of nature's harvest being over, there is nothing of significance to relate until beings resembling man made their appearance about a million years ago. We know little that is not somewhat speculative about the evolution of man, before the period of recorded history. It is thought, however, that a million years ago he knew how to initiate and control fire, and it would seem that his progress since then has been conditioned as much by the state of his technology as by any other single cause. For a very long time men remained gatherers as distinct from producers. They were content to take what nature provided and use it as best they could. Later they assumed a more active role and endeavoured to improve upon nature by tilling and fertilising the soil, using domesticated animals for work and food and fashioning tools of stone and metal to increase the range and usefulness of their endeavours. It was in this latter phase that the demand for fuel grew apace. Wood was required for warmth, for cooking and for smelting metal, and whole districts were deforested by burning for no other reason than to provide wood ash as a fertiliser. Large areas in India, China and other countries were devastated in this way, and when in these areas crops failed through lack of further enrichment of the soil, the population was decimated by starvation, and so the culture died that had blossomed in the previous age of plenty.

The record of these early civilisations seems to show that an improvement in technology

* Mr. Eccles is a member of the British Electricity Authority.

encouraged an increase in population which overshot the capacity of the reigning technology to feed and to clothe, with the result that, in the exercise of that strongest human instinct—self-preservation—man with his limited knowledge unwittingly cut off the branch on which he sat. Thus it was that lack of knowledge of what nature held in store, and lack of knowledge of how to use efficiently the known resources, caused cultures of high rank to wither and, in some cases, to vanish from the earth.

However, the pattern was not even and, in some areas, improving supply technology, aided by slave labour, was able to meet the increasing demand for long periods. By 10,000 B.C. men knew how to make bricks, by 6000 B.C. they began to tap the fossil fuels, beginning probably with the most accessible deposit, asphalt. Earthenware vessels were made as early as 5000 B.C. The Chaldeans were skilful metal workers by 4000 B.C. Limestone was calcined and enamelled pottery made in Egypt and Babylon by 3000 B.C. Asphalt was used in the building of the Pyramids and for waterproofing the walls of Jericho. In Babylon, roads were built by setting stones in asphalt, a practice revived by J. L. McAdam some 2500 years later.

About 1000 B.C. the Chinese were using natural gas for fuel and lighting, which they procured from wells 3000ft deep and transmitted in bamboo pipes. According to Herodotus, an oil well was working on the island of Zante in 400 B.C., the lighter fractions being separated by stretching a hide over a cauldron of boiling oil and wringing out the condensed liquid.

The earliest recorded use of coal is 1100 B.C. in China. At that time, Chinese technology was sufficiently advanced to enable them to produce saltpetre, arsenic, mercury, vegetable oils, paper, sugar, printing and gunpowder. The first use of coal outside China was probably in Greece, and there is evidence that coal was known and used in Britain before the Roman occupation.

These apparently isolated, but perhaps not unconnected, examples of technological progress coincided, in some cases, with quite advanced civilisations, but it may be significant that almost invariably an improvement in supply technology was accompanied by an increase in population and by an arrogance or indolence in the governing body, which formed the seed-bed of decay. In this respect, things came to a head round about 500 B.C. In 538 B.C., Belshazzar was slain on the night of the handwriting on the wall and the Babylonian empire came to an end. In China, industrial progress ceased with the full flowering of the Confucian philosophy, and in India the caste system withdrew all intellectuals from the industrial crafts. Greek industrial progress died with Alexander the Great.

These events and others ushered in a period of 2000 years of technological stagnation in which, whilst fuel was still used for heating, little further progress was made in establishing man's command over nature. This period includes the Greek and Roman civilisations, which made little attempt to revive fuel technology. Greek intellectuals scorned those who tried to turn technical theory to practical advantage, and, though the Romans invented the waterwheel and the concave mirror for concentrating solar heat, their source of energy was almost wholly that of slave labour and animals right to the end. What was needed was the discovery and application of means to augment man's energy and improve his transport. The Phœnicians had used the force of wind in sailing ships since 1000 B.C.; Hero of Alexandria came near to converting heat into work; the Romans used water power and the Chinese had used the explosive force of gunpowder. But no one knew how to harness nature continuously on the scale necessary to suit the growing human need.

It would be wrong to suggest that nothing happened anywhere during the Dark Ages. At the end of the Roman occupation, Britain experienced a political setback, but with the gradual emergence of more settled times the demand for fuel outstripped the current rate of vegetable growth and the countryside was being steadily denuded of its forests. Long before this, coal had been discovered as an outcrop and its value as a fuel was known. It was not a popular fuel, and in the reign of Edward I a decree was made compelling "all but smiths to eschew the obnoxious material and return to the fuel they used of old."

Thus we arrive at the fifteenth, sixteenth and seventeeth centuries A.D., with science and technology slowly awakening and facing the prejudices that had become entrenched in men's minds, without opposition, during their long period of hibernation. It was in this setting at the very end of the seventeenth century that an Englishman, Thomas Savory, invented the first successful steam engine and showed how heat could be converted into work. By means of this engine, improved by Newcomen and Watt, there was tapped an enormous reservoir of energy stored in the coal measures for 300 million years. The amount of power that was there for the taking seemed unlimited and the scale of human achievement made possible by this new mechanical aid dazzled the imagination. It was natural that the first applications of steam engines should be for pumping and winding at coal mines, but, once this main source of power energy had been made secure, their use became general. In 1827, the first steamship crossed the Atlantic to the New World, and in 1829 the first steam-driven railway locomotive was in operation. In 1884, Charles Parsons invented the first practical steam turbine, which so raised the sights in size and efficiency that to-day single machines are being designed for an output of 200,000kW using only ¼ lb of coal per kilowatt-hour.

Contemporary with these events in the realm of steam, work was in progress on the design of machines, in which controlled explosions of oil or gas could be translated into continuous mechanical power. The result was the internal combustion engine, which, apart from many useful fixed applications, completely revolutionised the mode, range and speed of transport. The first motor-car using this engine took the road in 1885, and the first aeroplane left the ground in 1903.

Prior to the emergence of most of these applications, Michael Faraday had discovered and demonstrated how a new and more versatile form of power could be made available. As every member of this Institution is aware, it was at the Royal Institution, London, on August 29, 1831, that Faraday first demonstrated the basic principle of electro-magnetic induction now used in every electric power generator throughout the world.

The result of these epoch-making inventions and discoveries has been that man, after surviving for nearly a million years on the gifts of nature as they were currently produced, and being frustrated from further development by the inadequacy of his technology, has in some parts of the world during the past 250 years developed a method of living that transcends everything hitherto achieved, but is largely dependent upon the use in enormous quantities of natural energy stored in a bygone age.

Earlier in this address, I suggested that the present use of energy was equivalent to the service of twenty slaves for each person on this island, and I posed questions on the chances of this state of affairs being maintained and what is likely to happen if the supply fails. I shall now attempt a qualitative answer to these questions in the light of current knowledge.

Coal, oil and natural gas are wasting sources of energy, and in due course will cease to exist. It has been estimated that, in this island already, we have raised 25,000 million tons of coal and that the readily accessible coal remaining is about twice that amount. On this basis and at a modest increase in consumption we shall exhaust the accessible coal in about 200 years. The total coal reserve is probably very much greater, but much of it would be extremely costly to win.

It is not easy to estimate the total coal reserves of the world, and although attempts to do so have been made, the results are subject to many qualifications—the thickness of the seam, the quality of the coal, its depth below the surface and many other things have to be evaluated before its economic worth can be assessed. Economic worth is a relative term which depends on the availability and cost of alternative fuels. Liquid fuel enjoys a somewhat special relationship to all others.

A recent American assessment of the world reserves of all fuels is shown in Table I.

TABLE I*

Fuel	World reserves	Source of data	Total energy B.Th.U.
			$\times 10^{18}$
Crude oil ...	610×10^9 barrels	Weeks and Moulten	3·5
Natural gasoline	$11{\cdot}5 \times 10^9$ barrels	American Petroleum Institute	0·07
Shale oil ...	620×10^9 barrels	Bureau of Mines ...	4
Natural gas ...	560×10^{12} ft³	American Gas Association	0·6
Coal	3482×10^9 tons	Bureau of Mines ...	72·2
Total conventional fuel	—	—	80
Uranium ...	25×10^6 tons	Raw Materials Division of A.E.C.	1700 at 1 : 1 breeding
Thorium ...	1×10^6 tons	Raw Materials Division of A.E.C.	71
Total new fuel (say)	—	—	1800

* Reproduced from Cisler, W. L.: "Economic Evaluation of the Industrial Use of Atomic Energy" (American Power Conference, March, 1953).

This estimate suggests that the world reserves of crude oil are only about 5 per cent of world coal reserves, whilst, with 1 : 1 breeder reactors, the potential energy of nuclear fuel is more than twenty times as great as that of the world reserves of coal, oil and natural gas put together.

The world annual consumption of coal is about 1600 million tons and the consumption of crude oil is about 640 million tons. Unfortunately, simple arithmetic is of little practical value in computing the probable life of respective fuels in particular countries. There are some undeveloped countries with considerable coal resources in which the present use is negligible. On the other hand, highly developed countries are consuming coal at a rate disproportionate to their reserves. Furthermore, not all the known reserves are recoverable, although, on the other hand, more may be discovered.

With regard to oil, it has been estimated that consumption in the United States will be doubled between 1950 and 1975, and if

this rate of increase were general the life of world reserves would be very much reduced. In view of the widespread tendency to use oil more extensively in agriculture and for sea, air and road transport, the supply of this fuel may easily become critical within the lifetime of the present rising generation.

This all-too-brief survey lends colour to the thought that, of the fossil fuels, oil will be the first to go. The efforts to produce a substitute liquid fuel may include the synthesis of coal, which, in turn, would accelerate the rate of destruction of this fuel. Even so, the reserves of coal are sufficient to allow time for the orderly development of alternatives. The geographical disappearance of fossil fuels will depend on the rate of uplift in relation to the amount of local reserves, and the rate of development of alternative fuels will depend, in the first instance, on their cost in comparison with that of local or imported fossil fuel. Obviously, the country with large reserves of all kinds of fuel is most favourably situated to maintain and expand its mechanised civilisation, and provided it uses these resources economically and makes commensurate advances in its political and cultural life, it is probably destined to remain a world force for a longer period than other less well-endowed peoples. The importance, therefore, of the economical use of native fuel stretches far beyond the desirability of maintaining one's standard of living, although it includes it.

What, then, are the alternatives to fossil fuels ? The general answer is nuclear fuel. I think, however, it would be wrong to give the impression that, although nuclear energy is there for the taking, it is a simple matter to release it in quantities suited to our requirements. Hitherto heat has been obtained by amputating and regrafting the limbs of matter ; in nuclear fission, it is proposed to tear out and divide its heart.

It is not possible to make an accurate forecast of what the future fuel situation will be. There are so many imponderables, the frontier of knowledge is being constantly expanded, Nature herself may take a hand as in the previous Ice Ages, and the reaction of humans to changing circumstances must be given due weight.

The increase in world population is an important factor. Ever since man's emergence from the Dark Ages, world population has been increasing. Curiously enough, this has been noticeable even in countries where technology showed no advance. Perhaps the general trend has been made possible through better means of communication whereby the effects of industrial technology and medical science are felt beyond the confines of the countries that initiate them. Whatever the reason, most countries have participated in the production of a world population which has enjoyed a four-fold increase during the last 300 years and is now growing by 20,000,000 a year—that is, by more than 2000 an hour.

The fate of previous civilisations has been sealed when population outstripped the ability of their technology to provide sustenance and shelter, and the fate of our own cannot be dissociated from this self-same influence.

In this welter of possibilities, it may be of value to look at two possible alternative situations—one on the assumption that nuclear fission or nuclear fusion will not prove to be a practical means of providing power, and the other that it will.

Without atomic energy, the main alternatives to coal, oil and natural gas are water power, tidal power and wind power, with solar energy and geothermic heat available in certain zones, and wood, peat and animal wastes, each making its own contribution.

Water Power

The conditions which make water power most readily available are adequate rainfall on a large elevated catchment area, a suitable reservoir in which to impound water at this high level, a relatively steep conduit to a low level where the power unit is situated, and adequate means for disposing of the spent water.

Hitherto the assessment of world inland water power resources has included only those which show prospect of economic development and are not required for other purposes such as navigation, irrigation or domestic use. In future, much more may be pressed into service, perhaps for dual purposes of which power will be one. However, the most recent estimates show that the world total of inland water power, 40 per cent of which is in Africa, could supply at least three-quarters of man's present energy requirements.

One of the largest and most spectacular sources of water power lies at the western end of the Mediterranean. This inland sea loses water through evaporation which is not wholly recovered from its river inflow, with the result that water is constantly flowing through the Straits of Gibraltar, and to a lesser extent through the Dardanelles. If, therefore, both straits were dammed, the level of the Mediterranean would gradually fall, and having established a suitable differential it could be maintained by admitting water from the Atlantic through suitable turbines. Rough calculation shows that, with a differential of 70ft, the inflow could develop 12,000,000kW, which is 75 per cent of the present demand for electricity in Great Britain. It would require a modern Hercules to undo the work of his illustrious namesake, and no doubt the political repercussions would be considerable. The project is mentioned here only to illustrate the kind of thing that may have to be done in a more civilised world of the future when coal has ceased to be.

Tidal Power

Tides are produced by the combined gravitational effect on the earth of the moon and the sun. Since the liquid portion of the earth's surface is free to move, large oceans respond to the differential attractive force at the nether and the further shore. Winds and currents also play a significant part. The result is that, at any given point on the coastline of a large ocean, the tidal lift normally varies cyclically twice in the course of a lunar day, twice in the lunar month and twice a year. The amplitude of tidal lift varies from place to place. Since tides follow the moon and man's efforts follow the sun, the tidal cycle is not co-ordinated to human needs and, in this sense, tides are an unsatisfactory source of energy.

The simplest device for using tidal energy is to trap water in an estuary, or reservoir, at the time of high tide, and after the tide has receded sufficiently allow the trapped water to escape through turbines in which most of the energy due to the differential head is converted into useful work. The daily work periods are cyclic, and their incidence in time of day also traverses twelve hours during each lunar month. There are devices, such as pumped storage and double-basin working, by means of which the energy available for external work can be controlled and better fitted to human requirements. There is also a difference of up to two hours in the time of high tide at different places round our coast. If a powerful electrical transmission system were available to connect together all such points, it would be possible to take advantage of these time differences to reduce the amount of pumped storage. So long as the harnessed tidal energy formed a small proportion of the total energy in the electricity system to which it was connected, it could be accepted as and when it was available without storage. The largest single tidal scheme in this country is that known as the Severn barrage, and much thought has been devoted to the most effective way of harnessing the energy in this estuary. A number of comparable schemes are being investigated in other countries, but no tidal energy project has yet reached the construction stage.

Energy of the Wind

Force is required to move air from one place to another, the corresponding energy being proportional to the cube of the velocity. It is practicable to abstract some of this energy by slowing down the speed of air movement.

Because of the low density of the medium, the energy release per unit volume for speed changes likely to be achieved in any practicable windmill is quite small. Stated conversely, a windmill must be a bulky structure with large-diameter vanes for even the relatively small output of 100kW contemplated in recent designs. Furthermore, the wind bloweth where [and when] it listeth. It would seem that, although there is a large amount of energy of movement in atmospheric air treated globally, practical considerations will limit the contribution to be made by this source to a small proportion of man's present-day energy requirements. However, even this contribution may be welcome when coal and oil have disappeared.

Solar Energy

The amount of solar energy reaching the land areas of the earth's surface is equivalent to 10,000 times man's present requirements, and this may be the source from which the final scientific civilisation will obtain its energy. Unfortunately, owing to the moderate temperature, the low intensity and the daily and seasonal variations, there is little hope of producing mechanical power by present known methods in any but tropical and semi-tropical regions. Interesting developments are taking place in domestic space heating and in solar cooking. Some 6000 solar cookers are being sold in India per annum, each capable of cooking a vegetable meal in about twenty minutes. If this practice extends, hundreds of millions of people will be able to cook their daily meal all the year round without using animal waste for fuel. Soil fertility should improve correspondingly.

Neglecting, therefore, for the moment the possibilities of nuclear fission, the most reliable and economical alternative to coal and oil is water power if one looks at the world as a whole. However, the locations of possible water power projects are such that quite fantastic power transmission schemes would be required to transport the energy to present centres of population. Apart from the political implications of such energy transfers across national frontiers they present technical problems of a scale and type quite beyond anything that has been solved hitherto.

An alternative to transmitting the energy to the people is to transport the people to the energy source, and a considerable shift in the weights of population may well take place in the future if nuclear fission proves to be intractable as a source of industrial

power. Great efforts would, no doubt, be made to ease the situation by developing tidal, wind and solar power in localities where there was little water power.

The foregoing assessment of the situation which may arise in the absence of a successful outcome of the attempts to harness the fission or fusion process for industrial purposes suggests that, when coal and oil are exhausted, it should be possible to muster man's present-day energy requirements from all the known sources, but that energy transmission or population transportation would present enormous technical and social problems. It underlines the absolute necessity to master the fission or fusion technique if the present pattern of civilisation is to endure.

Nuclear Energy

Let us now look briefly at the nuclear power possibilities.

Professor Einstein postulated that matter could be converted into energy. He calculated that the annihilation of 1 lb of matter would release energy equal to 11,340 million kWh of electricity. Were such complete conversion possible, 6 lb of matter would release energy equivalent to the whole of the electricity generated in Britain last year. No means has yet been found to achieve this result.

It has been possible, however, to release a tiny fraction of the mass energy of matter by persuading a heavy atom to divide into two lighter atoms whose combined mass is a little less than that of the heavy one. Similarly, it has been possible to release energy by persuading a number of light atoms to form a single atom whose weight is a little less than the sum of the weights of the lighter atoms which combine to make it.

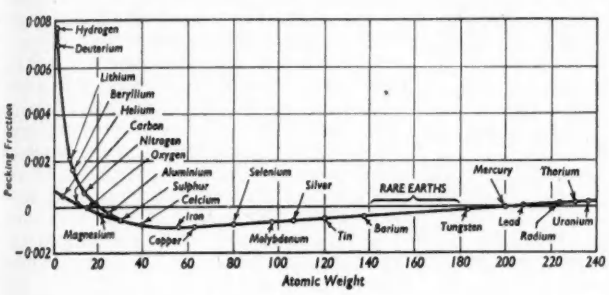


Fig. 1

Fig. 1* illustrates some of the possibilities. In it are shown the deviations from whole numbers of the atomic masses of a number of elements on a scale in which the mass of oxygen is taken as 16. Some of these deviations are positive and some negative. Theoretically there should be a release of energy when atoms with a more positive mass deviation divide or combine to produce atoms of less positive or of a negative mass deviation. The division of uranium into two lighter elements or the fusion of hydrogen into helium offers the possibility of energy release. The diagram suggests that there are other possibilities.

Since hydrogen constitutes a substantial proportion of the earth's crust, the potential energy from the hydrogen-helium fusion process could be enormous. A practical difficulty is the sustained temperature at which this reaction takes place, and it would seem that, until something is discovered which will enable the reaction to proceed at a lower sustained temperature, the industrial application of this great energy source will remain unsolved.

From published data on the fission of uranium, it would seem that the process can be controlled in such a way as to liberate heat at a temperature suitable for industrial power purposes, but that before efficient large-scale nuclear power stations are practicable, work has to be done on heat transfer methods and materials and on the treatment of the products other than heat which form part of the process. There can be little doubt that these problems will be solved if the need to do so is sufficiently great.

Of the uranium existing in nature, only about 0·7 per cent is fissile. However, a process has been devised through which the remaining 99·3 per cent can, by a double reaction, be converted into plutonium, which is fissile. Thus it is now theoretically possible to release in a controlled manner the energy of fission of all the uranium and perhaps the thorium content of the earth's crust. The practical and economic problem is to find the uranium and to separate and purify it.

From this point of view it is unfortunate that uranium is so widely dispersed amongst the other materials of the crust. For example, it has been stated that the uranium content of a ton of granite, if it could be isolated, would produce as much heat as a ton of coal. However, there is no known economical method of isolating the uranium content of granite, and this is equally true for trace contents in many other common substances.

There remains, therefore, the problem of recovering pure uranium and thorium from their ores where they appear in forms and quantities that render the process economically practicable. It has been estimated that the availability and accessibility of uranium is such that (at present costs) an expenditure of £50 per pound of pure metal should be sufficient to mine and refine enough of this fuel to provide man's present energy requirements for 1500 years. Similarly, on the same basis, an expenditure on less productive ores of up to £100 per pound of pure metal should procure sufficient uranium to last another 8500 years. These very general figures should be taken only to indicate the satisfactory manner in which uranium can meet world energy requirements and, broadly, what effort would be required to render it available.

It is outside the scope of this address to forecast the international problems that may arise from the geographical distribution of fissile material in nature, but without wishing to minimise them it can be said that they will just have to be solved if all peoples are to enjoy the benefits of a mechanised civilisation.

There are some who argue that, because it is now theoretically possible for nuclear fission to satisfy man's total demand for energy, the pursuit of all other sources should be abandoned. I do not share that view. There are problems to be solved before the energy of fission becomes a reality on a large scale. The chemical process of uranium separation and purification will itself consume a considerable amount of energy, and in any event the alternative sources will be fully competitive for many years to come.

As coal and oil approach exhaustion, a possible balance may be found by harnessing all the water power of the world and, as far as possible, meeting local power requirements from this source. Where there is a local surplus of water power, the energy could be used to purify fissile material so as to provide power in lands where the alternatives are insufficient. Since fissile material, even in its natural state, is easily transportable; such packaged fuel might solve the power transmission problem.

Water power, tidal and wind power will, no doubt, be developed in many lands to minimise the need for imported fuel, and the world production of industrial alcohol will probably be greatly increased to provide much-needed liquid fuel. Indeed, one of the problems of the Atomic Age will be the provision of small mobile power units, and it may be that part of the answer will be found in the use of nuclear energy via a fuel cell. As far as can be seen at present, nuclear energy will be made available to the people as electricity. Electric rail and road transport will assume a new importance. Britain will become a smokeless zone.

In sum, therefore, man having evolved during a million years has, over the past 250 years, developed a mode of living which is unique in human history. This achievement has thus lasted for only 0·025 per cent of his sojourn here and already it has made great demand on the energy resources of our planet. Unless he is able and willing to match his technology to the unfolding needs of the situation, he has no prescriptive right to a continuance of this latest civilisation, and the history of civilisations discloses that discontinuity—decay and rebirth—is the normal method by which successive stages have been reached.

However, to-day man is equipped with a knowledge of natural laws (science) and an ability to harness these laws to his needs (engineering) that were absent in all previous civilisations, and there is good reason for thinking that the present mode of living can be greatly prolonged if he will but use this knowledge and ability aright. The test is one of competence in the political sense to learn how to live together in peace, and in the technical sense to unravel the unsolved relationships in nature and constrain them to serve his ends. The political aspect, though extremely important, and something for which all must share the responsibility, is outside our immediate scope this evening. But the progress of science and technology is the main object for which this Institution exists and, as events are shaping, is one of the two vital matters that will condition the future of the human race.

These twin challenges must be met if civilisation is to endure, and members of this Institution are in the front line on one of the battlefields. It is an exciting situation. The need for more and better physicists, chemists and engineers was never more clamant, the results of achievement were never more worth while, and it is extremely important that in our homes and schools the need and the prospect should be fully explained to the rising generation on whose shoulders the responsibility for continuity lies.

We stand before the portals of an epoch. It is the privilege of scientists to unlock one of the doors through which humanity may pass to the enjoyment of a fuller and a freer life for the next 5000 years.

Let us all see to it that man is worthy of his achievements.

* Reproduced from Kendall, J. T.: "The Production of Atomic Energy," *Engineering*, 1946, 161, page 75.

British Shipbuilding Research Association.—We are informed that at the annual general meeting of the British Shipbuilding Research Association, held on September 30th, the Council of the Association elected Mr. Charles Connell a chairman and Mr. J. W. Elliot as vice-chairman for the ensuing year.

Institution of Naval Architects

AUTUMN MEETING

No. III—(*Continued from page 496, October 8th*)

THE second paper read in the afternoon of Wednesday, September 22nd, at the autumn meeting of the Institution of Naval Architects in Torquay was :—

SCALE EFFECT EXPERIMENTS ON "VICTORY" SHIPS AND MODELS. PART I: ANALYSIS OF THE RESISTANCE AND THRUST-MEASUREMENTS ON A MODEL FAMILY AND ON THE MODEL BOAT "D. C. ENDERT JR."

By PROFESSOR DR. IR. W. P. A. VAN LAMMEREN, DR. IR. J. D. VAN MANEN AND IR. A. J. W. LAP.

SYNOPSIS

This paper deals with the resistance and thrust-measurements on a series of six geometrically similar "Victory" ship models, ranging in scale from 60 to 18, and on a "Victory" model boat of scale 6.

The first part of the paper gives a description of the ship, the propeller, the models, the test apparatus, the test performance, the instrument calibration and the necessary corrections.

The measured resistance and thrust values of the model boat are correlated with the results of the tests with the models using three methods, i.e. the Schoenherr, the Hughes, and the Lap-Troost extrapolators.

The results of experiments for the determination of the wall-interference are given. These experiments are based on the principle of the "image method."

An attempt is made to analyse the thrust deduction factors as a function of the Reynolds number.

Conclusions and a programme for the continuation of the tests are presented at the end of the paper. Test measurements of the models and the model boat are tabulated in the Appendix.

DISCUSSION

Dr. R. W. L. Gawn : Our Institution is fortunate to have such a full account of the first fruits of the comprehensive research outlined by Professor van Lammeren in his paper presented at our meetings in Holland last year.

Much interest will be centred on the bearing of the results on the skin friction formulation. Six models of the "Victory" ship were tested, ranging in length from 7·4ft to 24·7ft, and of a model boat of 74ft length. A reasonably close prediction of the measured resistance of the boat is obtained by each of the three skin friction formulations from the results of tests of models. This is subject to a rather arbitrary form factor being accepted for two of the formulations. Predictions for the shortest model from the Schoenherr line are about 3 per cent in excess, but about the same as for the larger models, according to predictions from Hughes and from Lap-Troost. This is well-established for the load condition and closely applicable to the light condition. In other words, the gradient by Schoenherr is a little too shallow for the wide range of models and for the other two formulations a little too steep, but the latter is avoided if the arbitrary form factor be accepted. The differences are not really marked and do not appear of first importance.

At a meeting last month of the International Towing Tank Conference it was decided to seek an agreement on a formulation for practical purposes on or before the next conference. The aim is to obtain a formulation which will stand the test of a long period of time, something like the time that that of Froude has stood. Much effort is being directed towards the determination of a true physical formulation. I feel that what Mr. Wigley told us yesterday had a bearing on that. He worked back to Navier's equations of 1830 for a viscous fluid, and until they are solved I doubt whether we shall solve the true physical formulations. The investigations described in the paper will be of guidance in this search for a practical line, although it will be necessary to check the import of Froude and other formulations. However, full results are given in the paper from model tests, so that this can be investigated to seek the effect of other formulations.

Many of the formulations that have been proposed show a fair margin of agreement for the skin friction resistance of long, fast ships, concerning which reliable information is almost absent, whereas there are small but strange differences over the model range despite the abundance of results at this end of the scale.

These tests of the model boat afford a good point beyond the model range. But the real requirement is firm information on the resistance of actual ships. This was emphasised in the report of the British Association for the Advancement of Science in 1867, but the only real response has been the old tests of "Greyhound" and the recent tests of the "Lucy Ashton." The results for the latter are accurate and reliable ; but the "Lucy Ashton" is a short ship. The "Victory" ship is about two and a half times as long, and I suggest that the authors consider including the measurement of towing resistance of a "Victory" ship in their future programme. Such a trial is vital and we cannot get by without it.

The alternative approach through shaft thrust measurements has certain limitations, and this is brought out from the thrust measurements on the model boat in the paper. One surprising feature of these results was the decline in thrust deduction factor with the roughened surface. This is contrary to the results given in my 1942 paper, on roughened hull surfaces, presented to the North East Coast Institution. A few models were tested at Haslar with roughened surface ; the hull efficiency elements were mentioned, and the thrust deduction factor appeared to be nearly the same as with the smooth surface.

There is a real advance in the approach to the determination of wall effect on resistance through images and I was relieved that the authors concluded that the wall effect is negligible, even for the largest model tested. Perhaps the authors would be good enough to indicate the wall effect deduced from the approximate blockage formula. It would be helpful in appreciating this if Fig. 18 were in coefficient form.

If the air resistance in Table V for fore and aft motion were expressed in coefficient form, it would facilitate comparison with other classes of ships, and also a statement of the percentage additional resistance due to air.

Professor G. Aertssen : This part of the "Victory" work of the Netherlands Ship Model Basin is an important step in the direction of the establishment of an extrapolator for ship-model correlation. It gives valuable information on the minimum turbulent friction line as far as nearly log $R=7·8$.

An extrapolator must be established on small models and, in the mind of the authors, a smooth model boat. For log $R=7·8$ the Prandtl-Schlichting diagram requires a limiting grain size 0·020mm, or 800 micro-inches for the hydraulically smooth model, and the authors, after careful treatment of the submerged portions of the boat, expect the model to be smooth.

Several times during the past months, roughness measurements on ships were undertaken in Belgium. The smoothest ship investigated had a Nikuradse number of nearly 0·050mm, or 2000 micro-inches, while the best sample plate had a Nikuradse number of 0·026mm, or nearly 1000 micro-inches. Although the sample plates were smoother than the ship herself, I feel that a hull surface finished with the care described by the authors cannot have a grain size of more than 0·020mm, or 800 micro-inches, even after allowance is made for structural roughness. This may reassure the authors, who are planning roughness measurements with painted plates.

I agree that roughness measurements taken by means of the Talysurf give a much better description of the surface than a pneumatic tester, but it is difficult, after analysis to translate them hydraulically. Boundary layer measurements were taken by means of a Pitot tube. These measurements certainly must give information on the smoothness of the hull, and I was somewhat surprised not to hear more about them.

Professor E. V. Telfer : The paper shows how far we are away at times from the view of the subject which William Froude took so many years ago. I want to make a suggestion to the authors in regard to the second of the objections mentioned, in their introduction, to William Froude's classic method, where they state : "It is open to doubt whether the approximation of the frictional resistance of a hull form by means of that of the equivalent plate is permissible for practical purposes." They use the term "equivalent plate," and I have a suspicion that I introduced the term "equivalent plank" into the subject in my 1922 paper before the North-East Coast Institution. I do not think that as a profession we are clear what is meant by "the Froude equivalent plank." Froude said that a ship form extrapolates exactly the same as a plank having the length and the area for the ship model. That has been the fundamental statement of the problem. It is not clear whether Froude ever applied that fundamental principle ; but in my submission the fundamental principle still stands and ship forms will extrapolate in exactly the same manner as a plank having the same length and surface. In short, Froude said you must change the slope of the extrapolator depending on the length/breadth ratio of the model.

In 1927 I gave a method of combining the Froude and the Reynolds laws which really included the Froude case, a special case, and one of the terms I introduced then was "extrapolator." I suggest to the authors that if they will use either my own or Dr. Hughes's work to calculate the true equivalent length/breadth ratio for these "Victory" models they will find there is no better extrapolator possible than that of the simple equivalent plank, and that goes right back to Froude's original concept.

The authors have been quite emphatic in their first paper, before they had the enlightenment of their own appendix, that the Schoenherr line is too flat. That is quite true, and it also disposes of anything they might find within the application of the Prandtl-Schlichting line, because that line differs by only 0·0001 from the Schoenherr. Therefore, the extrapolation of the Prandtl-Schlichting must be identical with that by the Schoenherr line, and if the Schoenherr is dismissed, the Prandtl-Schlichting should be dismissed.

The curse of the Schoenherr line is that it

allows experimenters to deceive themselves. The difficulties of experimenting are twofold. In the first place, the trouble is that with small models the trouble is to get rid of laminar flow. When they come to wall effect, the Schoenherr line, by coming above the true extrapolator, apparently deludes them into thinking they have no such effect. If the Schoenherr line accurately allowed for laminar flow and wall effect we should have no grouse, but obviously it cannot allow for those differences. You must be able to say that there is no such thing as wall effect and laminar flow on our models. If there had been time to re-present the author's work we should have seen how severely the experiments suffered from laminar flow right up to 16 knots.

A major problem before experimenters is the accurate determination of the turbulence resistance and the elimination of laminar flow from the results. Unfortunately, the authors have not succeeded in eliminating laminar flow, and I feel they place too much hope on the putting of a 1mm wire around the models to establish turbulent flow. They will have to adopt many different methods of inducing turbulent flow and proving that laminar flow has been eliminated.

In the investigation of thrust deduction scale effect the authors have found that the thrust deduction increases with the size of model. What I feel is happening is that, with the curious reaction type rudder on the larger models, thrust deduction appears to be increasing because the resistance of the rudder is climbing up a transition line, whereas for the smaller models there is only a small rudder resistance. Rudder resistance must not be allowed to confuse our knowledge of thrust deduction and I am sure the authors will expand their work to find out just what the rudder resistance is in each case and separate out the results from the total thrust deduction.

Dr. S. Livingston Smith: Their work on the 72ft model boat is the nearest to our "Lucy Ashton" experiments. I ask whether any wake and rudder effects from the towing vessel have affected the towed vessel, and whether any experiments were carried out to ascertain that the towed vessel was or was not affected. I suggested the use of jet engines in the B.S.R.A. experiments because doubts were expressed as to whether we could tow a vessel satisfactorily and obtain accurate measurements of resistance. I knew that the jet engines could give a perfectly constant thrust. Did the authors of this paper find a variation in the towing pull during the trials on the model boat ? As Dr. Gawn has remarked, the 72ft model boat is quite a long way from the ship. We did our experiments on a 200ft ship. Do the authors intend to carry this work further and tow a full-size vessel ?

Dr. J. F. Allan : The Dutch tank people have devoted great thought and trouble to achieve the necessary accuracy both in the model work and the model boat work ; it is essential to attain high accuracy to be able to draw useful conclusions from the results. I should like to know how the speed was determined when towing on a long line. Was it determined from measured distances on the shore, or by a Pitot method or by other means ? The results of the paper have a great value in relation to the question of surface friction and extrapolation. The conclusions arrived at are interesting, namely, that the tests indicate that the Schoenherr line is too flat and that the Lap and Hughes methods give good agreement, using suitable form factors.

This whole question of the study of surface friction extrapolation may appear to many to have been given unnecessary amount of attention by those of us who are particularly concerned with this research. But it is important to determine the true extrapolation from the point of view of determining the performance of an absolutely smooth ship. If it is as determined by the Lap and Hughes extrapolation methods, we can achieve a considerable reduction of power on existing ships by achieving greater smoothness.

The question of form factor is a true approach to the subject, but it will be difficult to settle and it will be years before we eliminate all the snags. We have determined to obtain a practical decision on a method which can be agreed on internationally at the earliest possible date.

In an appendix the authors indicated further work which was done with models down to very small scale, and the diagram appears to indicate an interesting general picture of agreement. But there are clear indications of laminar flow on the smaller models, and I agree with a previous speaker that the use of very small models is dangerous, that unless care is taken to examine the extent of laminar flow or the success in getting turbulent flow, one is likely to experience trouble in dealing with this subject on the basis of extremely small models. It would be interesting if our Dutch friends could carry out full-scale tests on the "Victory" ships. I had the impression that that was the ultimate intention ; if so, I recommend the use of the jet engine method, as employed on the "Lucy Ashton."

Mr. H. Lackenby : The ship-model correlation has been carried out by three methods, namely, the straight Schoenherr, the Lap-Troost method (which includes a form correction), and the Hughes method (also including a form factor). On several occasions I have been accused of favouring the Schoenherr method, and I would like to correct that impression, for, like others, I am not quite sure ; when I see a copy of Dr. Hughes's paper I may be more definite about it.

I suggest that in this paper the authors have been a little unfair to Schoenherr. I refer to the form factor. The Schoenherr appears only to be a skin friction formulation for smooth surfaces.

I am surprised that in the authors' experiments the wall effect turned out to be so small, because in the "Lucy Ashton" tests we made a correction which was criticised for being on the small side. I agree with Dr. Allan that it is dangerous to draw too many conclusions from the use of small models, because there is the problem of laminar flow, and I think it may well re-establish itself after the turbulence stimulator. Another bogey when experimenting with very small models running at very low speed is this question of laminar separation, and unless you are sure that it is not happening you may be misled. On the question as to how thrust deductions are reduced with increasing resistance of the hull, I wonder whether it may not be constant suction on the ship.

Professor van Lammeren, replying to the discussion, said : One of the main points raised is that the Schoenherr curve seems to be too flat and that the Hughes extrapolator is a bit too steep. Dr. Gawn has asked if we can agree with this. We can agree, but we must be practical and consider what is the result for the actual ship when using the Schoenherr line or the other extrapolators. I think every model basin has to build up its own system. I could show you a list of fifty or 100 results of ship trials and service operation which show that the allowances we get as the result of applying the Froude method are not so bad. In future, when we have decided to use a certain line, we have to build up our system for making allowances.

We have been asked whether we are going to extend our tests to the actual ship. We hope to do so, and it has always been in our programme. We hope to do so by towing the actual ship in the Red Sea. But first we shall have to carry out other tests, such as measuring the wake distribution behind the ship with the turning of the propeller.

Dr. Gawn was surprised that the thrust deduction fraction declines with the roughness of the surface. That is quite obvious, because with the smooth model you have a higher loading of the propeller. It may be due also to the fact that the circumferential inequality of the wake is less with the rough model than with the smooth model, so that for the ship it may be less.

Professor Aertssen has referred to the roughness of the model boat. I do not think the model boat was very rough. If you apply the Schoenherr or other extrapolator you get a difference of 3 per cent, which I think is not very much. However, if it does appear that the model boat has been too rough we can repeat some of the tests with a still smoother surface.

Professor Telfer refers to the equivalent plate expression and suggests using a plate having the same length as for the model. But what about the boundary layer ? The thickness of the boundary layer on the plate will be quite different from that on the model. We think it would be better, instead of using such a plate, to use rotational or double models. We did not analyse all the results by using all the various methods, because of lack of time ; that is one of the reasons why we have given the results in tabulated form, so that anybody can do this work on his own behalf.

As to the doubt expressed concerning laminar flow on the small models, we repeated our tests many times and we obtained very good consistency in the results. I think it is a good suggestion to repeat some of the tests without rudder.

Dr. Livingston Smith mentioned propeller race effects on the resistance of the model boat. The distance between the model boat and the towing boat was 170m, and the race of the propeller was not in the centre, and I am certain the propeller did not influence the model boat. For measuring speed we used Pitot tubes, and the measurement apparatus was calibrated on the measured mile. We repeated the tests many times and always got the same results.

Mr. Lackenby was surprised that the wall effect was much smaller than in the case of the "Lucy Ashton." One of the reasons may be that the "Lucy Ashton" was running in shallower water and at greater speed.

(To be continued)

CONCRETE STRUCTURES IN ITALY.—A party of eighty architects, engineers and contractors returned to London recently after a week's visit to Italy, during which they inspected new concrete buildings and civil engineering structures in Milan, Turin, Bologna, Florence, and Rome. The visit was organised by the joint committee on structural concrete (representing the Cement and Concrete Association, the Prestressed Concrete Development Group, and the Reinforced Concrete Association). Among the more important works visited were the thirty-storey skyscraper, the "Lanerossi" and "Sirti" buildings and the Pirelli garage in Milan, the exhibition palace in Turin, the Ministry of Public Works building in Bologna, the stadium, the Lazzi coach garage, and the reconstructed bridges over the Arno in Florence and the exhibition area near Rome. The party was impressed, the Cement and Concrete Association states, by the number of important housing schemes they saw, and particularly by the extent to which the Italians are everywhere building upwards. Each city had its blocks of new flats, not only within the town but on new and self-contained housing estates on the outskirts, and in all cases, we are informed, the tall buildings were "attractive and eminently liveable."

Mobile Electric Rotary Drilling Equipment

A mobile, electrically operated, rotary drilling equipment for use in an iron ore mine has been developed by F. Taylor and Sons (Manchester), Ltd. Its operations are remotely controlled through push buttons from a portable panel and it drills holes up to 10ft deep on faces 18ft high by 24ft wide without need for manœuvring its carriage.

PARTICULARS have been received from F. Taylor and Sons (Manchester), Ltd., 136/140, Bolton Road, Pendleton, Salford, of a new mobile electric rotary drilling equipment developed for iron ore mining and built for use in the Dragonby mine of the United Steel Companies, Ltd. With this machine all the holes on a face 18ft high by 24ft wide can be drilled to a depth of 10ft without further manœuvring of the carriage once it is in position. The drill rod is totally enclosed and fully supported to prevent wandering on initial penetration. By use of a portable control panel the operator can position it with complete freedom from close proximity to the working face.

The general construction of the drilling machine can be seen in the photograph we reproduce. It is mounted on a four-wheeled, pneumatic-tyred chassis of simple construction which is propelled by a geared, slip-ring 10 h.p. motor with an output speed of 92 r.p.m. from the gearbox. The drive is transmitted to a standard Ford 3-ton differential axle through a twin "Layrub" coupling. Sprockets bolted to the brake drums on this axle transmit the drive through heavy duty chains to each of the independently mounted front wheels. The chassis has been built with a ground clearance of over 3ft, the very wet floor conditions prevailing in the mine having been borne in mind.

The driving controls are simple to operate and consist of a steering wheel ; a hand and a foot brake ; a driving pedal ; a forward-off-reverse selector switch, and an inching button for short moves.

The control of the traction motor is by rotor resistance controlled by contactors which are operated by sealed mechanical timers so that correct starting of the motor is achieved at all times. The control gear is strongly constructed, and is housed within a steel weatherproof panel. A trailing cable supplies power to this panel and all other services on the machine which has a maximum travelling speed in forward and reverse of 1·5 m.p.h.

The turntable is carried on a heavy steel ring through roller-brackets mounting pairs of rollers on the top and bottom of the ring, and it has a large central roller bearing pin. The table is turned up to 35 deg. in either direction by a pair of hydraulic rams through a chain reacting against a stationary chain sprocket bolted to the sub-frame.

The main jib is carried in trunnion bearings at the apex of a triangular plated structure attached to the turntable and is of braced angle construction, generally square in section. The outer end of this jib houses large cast iron bearing rings carrying a tubular extending portion which may be extended and retracted in relation to the main jib by means of a hydraulic ram. The tubular jib is constrained from rotating by means of a shoe attached to its rear end, which slides over a key bolted in the main jib. The range of the telescopic movement is about 6ft 6in.

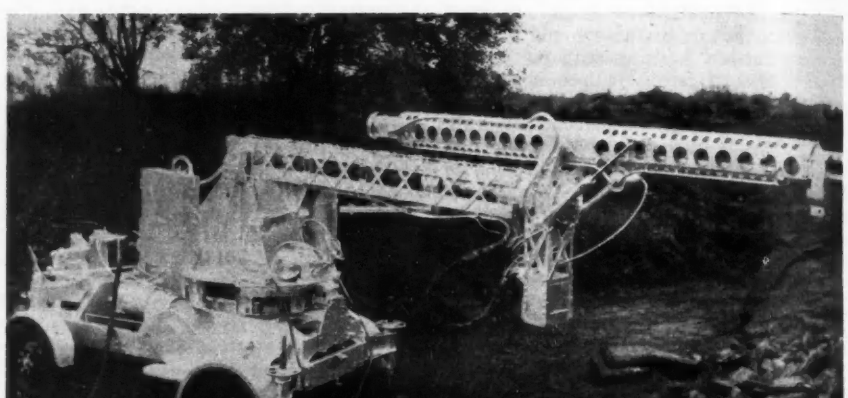
At its inner end the main jib has a bracket fixed to its underside and, through a large diameter hydraulic ram connecting the bracket to the turntable base plate, it can be elevated and depressed approximately 31 deg. above or below the horizontal position.

At the outer end of the tubular extending jib is mounted a split casing carried on a large cast iron bearing ring, and attached to this casing are two cast steel brackets which form trunnion bearings for the drill assembly. Within the tubular jib there is housed a "Helio-Centric" gear reduction unit which is driven by a ¼ h.p. motor. The reduction gear has its output shaft, which makes one revolution in approximately two minutes, keyed to the split casing and by this means the drill assembly can be rotated about the axis of the main jib.

Hydraulic rams between the drill assembly frame and the rotating head can swing the drill about its mounting trunnions from an axis parallel to the main jib to an angle of about 60 deg. This angular movement has since been increased to 90 deg. to enable cross cuts to be opened out.

As can be seen from the drawing reproduced on this page, the drill assembly itself has a pressed steel octagonal frame which is made up in four sections connected by longitudinal channels which also form slideways for a travelling gearbox. A 6 h.p., totally enclosed motor at the back end of the frame drives a double-reduction gearbox which operates a 2in diameter feed screw at a constant speed of 490 r.p.m. The travelling gearbox is driven from keyways in the feed screw and carries the drill chuck, feed and retraction clutches. This box has a maximum travel of 10ft 1in along the frame, its forward feed rate being 4ft per minute and its return or retraction speed about 47ft per minute. The speed of the drill chuck is constant in one direction irrespective of whether the drill is advancing or retracting.

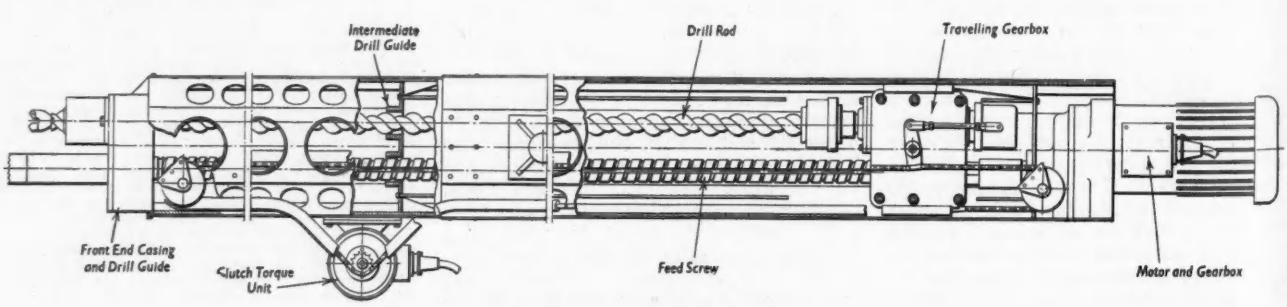
In the travelling gearbox the feed screw drives at a constant speed the first pinion which is freely splined to its keyways. This pinion drives the drill chuck shaft at the same speed as the feed screw. The drill chuck shaft has a dog clutch formed on its rear face and coaxial with the shaft there is mounted a floating clutch meshing with the feed pinion, which is threaded internally, to engage on the feed screws. When the floating clutch is moved to engage the chuck shaft the fact that the gear ratio between the dog clutch housing and the feed pinion is other than 1 : 1 imparts a differential speed to the feed pinion, which is propelled together with the gearbox. In this case a ratio has been chosen to propel the gearbox forward to give a drilling rate of 49in per minute.



Remotely controlled mobile drilling equipment for faces 18ft high by 24ft wide

The retracting mechanism uses the same principle, but in this case the floating clutch is moved to the left, thereby engaging the opposite set of dogs, one of which is keyed to the gearcase. The feed pinion then acts as a running nut on the still rotating feed screw and the gearbox is propelled to the left at a speed of about 560in per minute.

The control of the floating clutch is effected by a motor mounted underneath the drill frame. This specially wound 3-phase motor is connected through a chain running in conduits to the clutch lever mounted on the travelling gearbox. The torque unit can be energised in either direction to exert a pull on the chain in the selected direction and move



Arrangement of drilling jig assembly

the floating clutch to feed or retract as required. A clutch retaining mechanism positively locks the clutch in the selected position.

Primary control of all operations conforms to standard mining practice and is by low-energy electric circuits at 25V.

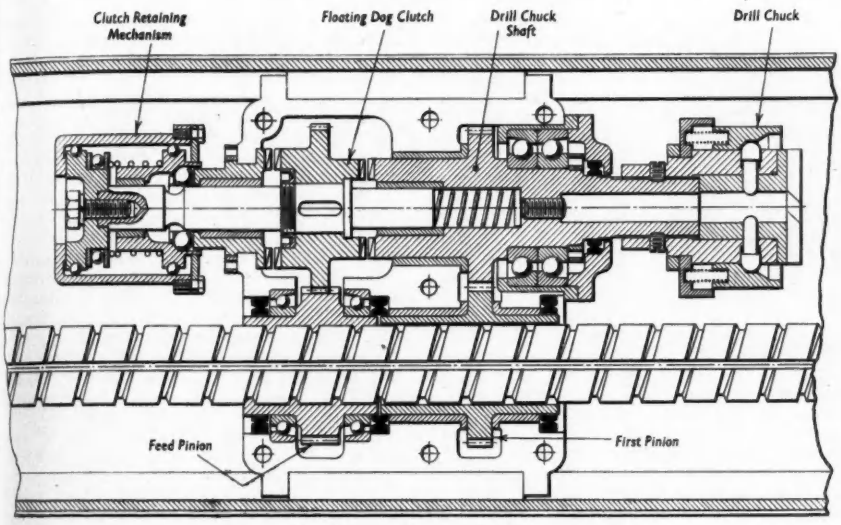
Voltages lower than that of the mains supply are provided by a 3-phase transformer of 1·5kVA capacity, which is furnished with double secondary windings of 125V and 25V, the former having the neutral point brought out to an insulated terminal for the provision of 72V.

Conventional overload protection is supplied for all motors, but there is a special circuit designed to overcome the difficulties of a choking drill rod which can occur owing to the damp conditions and characteristics of the iron ore. This has been achieved by the introduction of a device which automatically places the drill clutch to "Retraction" when a certain degree of torque is exerted by the drill motor.

Since the torque of the drill motor is directly proportional to the current consumed, a current relay is introduced into one phase of the motor supply and this operates at a point when approximately 125 per cent full load current is passing. Contacts on the relay operate a timing circuit and a pulse of one second duration is applied to the drill clutch torque unit, thus putting the clutch into the retraction position. The rod is then withdrawn from the hole, bringing with it the damp ore, causing the chokage. The drill clutch cannot be set to the forward drilling position whilst this overload exists, so that a large measure of protection is achieved.

The hydraulic systems are supplied from a pump, having an output of 3·3 g.p.m. and fitted with an unloader valve which by-passes the fluid back to the reservoir when not required. The maximum pressure available is approximately 1000 lb per square inch but all rams work at pressures considerably below this figure. The pump output is more than sufficient to deal with the four services, viz., main jib elevating ram, two turntable rams, jibs extension ram and drill frame rams, and more than one service may be operated simultaneously although at reduced rates.

The control circuits for the fourteen services of the equipment are brought to a central distribution box mounted on the turntable structure and a multi-core cable about 10 yards long is connected between this and a portable push-button control box. This box is carried by the operator who has complete freedom of movement to judge accurately the alignment and positioning of the drill.



Travelling gearbox mechanism

FACTORY EFFICIENCY EXHIBITION.—The Birmingham and District Industrial Safety Group is sponsoring another Safety and Factory Efficiency Exhibition, which is to be held at Bingley Hall, Birmingham, from June 24 to July 1, 1955. The last such exhibition in 1953 was visited by over 19,000 people. Full details of the exhibition may be obtained from Mr. W. G. Appleyard, Industrial Safety Training Centre, Newhall Street, Birmingham, 3.

Automatic Train Announcement System

PARTICULARS have been received of a new system of train announcement which has been installed at Stratford Station by British Railways. This system came into operation on Monday, October 11th and with it platform announcements for down trains on the Eastern Region lines from Liverpool Street to the Eastern Counties are automatically initiated by the individual trains themselves. This system, which is the first of its kind in this country, has been developed by The General Electric Company, Ltd., to the specifications and requirements of the signal and telecommunications engineer, Eastern Region, British Railways.

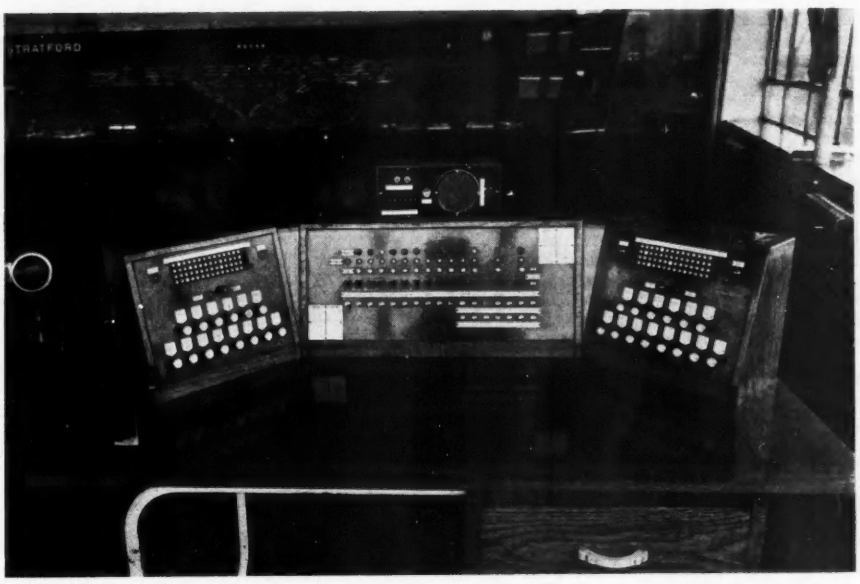
With the new equipment the announcements for the various trains are recorded on a continuous loop of magnetic tape, 3in wide, and having a capacity for twenty-five recorded tracks. The "train approaching" and "train standing" portions of each announcement are recorded on separate tracks. The appropriate announcement for any given train is selected by an operator in the signal-box and the selection is stored electrically until the train operates the track circuit connected with the signalling system, as it approaches Stratford Station. Thereupon, the play-back head is moved to the pre-selected track on the magnetic tape, which is set in motion at the same time. The tape reproducer, which is linked to the station loudspeaker system through an amplifier, then starts announcing: "The train approaching No. —— platform will call at ——."

When the train passes into the platform track it operates an adjustable delay relay. This allows a suitable lapse of time, before the doors open. The reproducer then broadcasts: "The train standing at No. —— platform will call at ——." During peak or abnormal periods, when the interval between trains does not allow sufficient time for the "approaching" announcement to be broadcast, this is automatically omitted, and the "standing" announcement only is broadcast.

The new control equipment at Stratford can be seen in the photograph we reproduce on this page. The telephone keyboard has push-button panels on each side and the recorded announcements are numbered and listed by each push button. The announcements are pre-selected and up to four pre-selections can be made and electrically stored in each platform group, an illuminated lamp indicating the announcement number of each stored selection. When the announcement for a train is started, a red lamp is illuminated adjacent to the respective storage indication and both lamps are extinguished when the train concerned leaves the platform.

With certain exceptions, a selection is made for every train that enters, or will enter, the controlling section of the line. Selections are made in the order that trains will arrive at the platform, irrespective of the order of entering the controlling track circuit sections or routing to the platform. Non-stopping trains, light engines and other traffic for which no announcement is necessary, but which will occupy the platform track circuits, are included in the selection by operating the "no announcement" key. In the event of an alteration, or incorrect selection, the stored selections can be cancelled and fresh selections made.

An audible and visual warning is given if a train for which no selection has been made, enters the controlling section. A selection can then be made at any time prior to the arrival of the train at the platform, but if sufficient time is not available for the broadcasting of the "train approaching" portion, this is automatically omitted. The announcements may



Keyboard and push-button panels of train-controlled announcement system at Stratford

be checked by means of a monitor loudspeaker and special or emergency announcements may be made by microphone to any or all platforms, including those of the up lines.

The control apparatus consists of British Post Office design telephone relays and uniselectors fitted in a metal cabinet. On the receipt of a start signal from the control apparatus, a uniselector rotates and is stopped at its appropriate contact, thus positioning the reproducing head on the required track. The tape motor is then started and, simultaneously, all high-tension circuits are completed, via relays, on the amplifier rack associated with the particular reproducer and the announcement is broadcast. The ends of the loop of tape are joined by a metal foil strip. This strip completes a circuit for the stop relay at the end of the operation and the reproducer and amplifiers are returned to the condition of awaiting the next start signal.

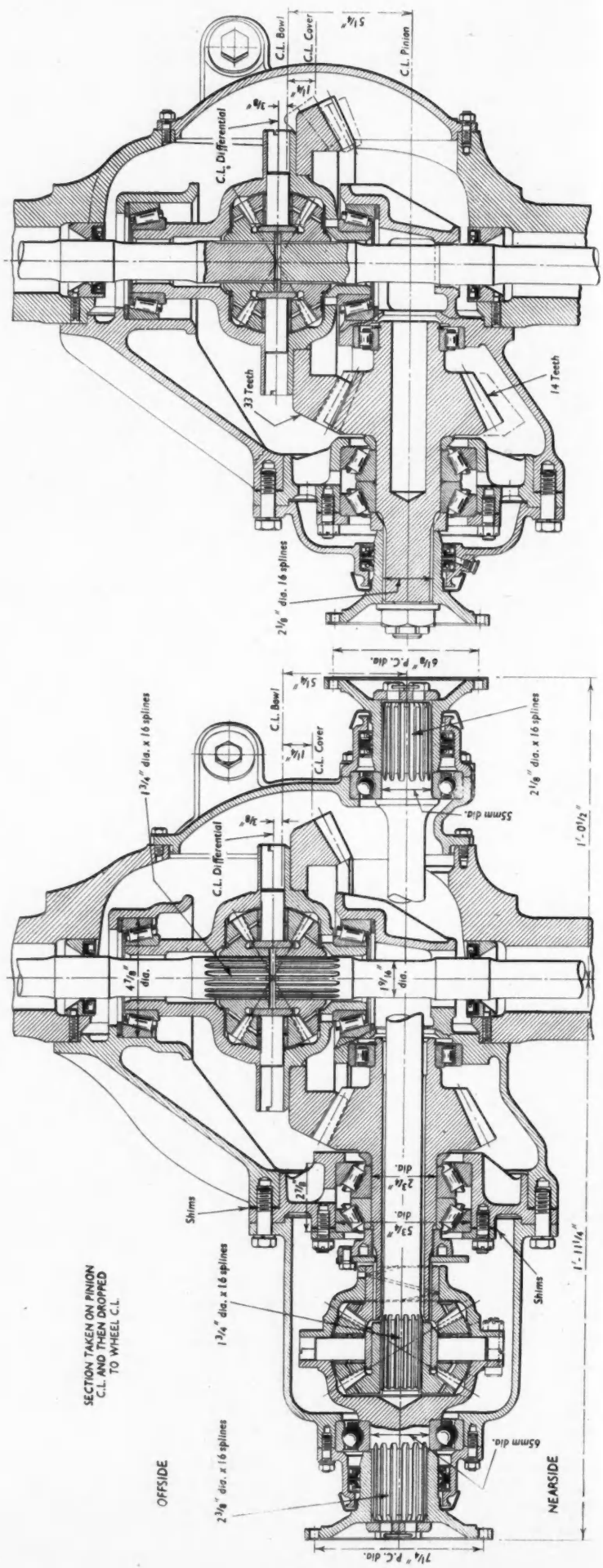
The tape is driven at a constant speed of 7·5in per second, by rollers and gearing, from a $^1/_{20}$ h.p. motor, and after passing under the reproducing head and main capstan rollers is allowed to fall freely into one end of a specially designed casket. The width from front to rear of the casket only slightly exceeds the width of the tape, which is thus guided to form folds that are gently removed as the tape is extracted from the other end of the casket, from where it is again drawn to the reproducing head. By this method approximately 30ft of tape is accommodated in a container 17in long by 7½in deep.

Three racks of amplifier equipment are provided, two for the recorded announcements and one for microphone announcements on the up platforms. Each rack is fitted with identical equipment, consisting of a monitor loudspeaker and output level meter panel, switching panel, tape play-back, pre-amplifier, power amplifier, relay panel and power supply control panel. The switching panel provides a ready means for connecting the rack equipment to either reproducer and to any loudspeaker group.

Institution of Engineers and Shipbuilders in Scotland

LAST Friday there was held in Glasgow the annual "James Watt" dinner of the Institution of Engineers and Shipbuilders in Scotland. The toast of "Engineering and Shipbuilding" was proposed by Commander Galbraith, Joint Under-Secretary of State for Scotland. He remarked that engineers and shipbuilders contributed more than any other industries to the exports of this country. There was at present every indication of economic prosperity and the trade "barometers" seemed all "set fair." About one-half of total world trade was conducted in sterling. The reduction of that trade "gap" which had troubled the country after the war was largely due to increases in engineering and shipbuilding production. There was, however, uncertainty amongst shipbuilders about future orders and some smaller yards already needed work. In reply, Sir A. Murray Stephen, past-president, said that in shipbuilding the storm warnings could be seen flying through lack of orders. But we were a peculiar people who tended to put off taking action until the need was urgent. How much more comfortable it would be if we did the wise thing beforehand! Other countries now had their shipbuilders subsidised, not taxed. In the United Kingdom money was being drained away from shipbuilders by taxation while at the same time air transport was being subsidised. Sooner or later a Chancellor of the Exchequer would have to do very much more for shipping. A new emphasis ought to be given to production in shipyards; and wages could not rise unless productivity rose, too. The toast of the "Guests" was proposed by Mr. Jackson Millar and Admiral Sir Angus Cunninghame Graham replied.

BRITISH WELDING RESEARCH ASSOCIATION.—Open days are to be held at the Metallurgical Laboratories of the British Welding Research Association on Tuesday, November 23rd, and Wednesday, November 24th, 1954, at 29, Park Crescent, London, W.1. Researches on both ferrous and non-ferrous alloys will be displayed covering many welding processes, including the argon-arc, metal arc and self-adjusting arc processes. For tickets of admission application should be made to the Secretary, British Welding Research Association, 29, Park Crescent, London, W.1.



Elements of transmission for 24-ton bogie, showing the arrangement of the three differentials with the intermediate shaft and wheel hubs removed

Heavy Axle Drives

Details are given herewith of a double hypoid drive bogie and of a 30-ton driving axle, both of which have recently been developed by Kirkstall Forge Engineering, Ltd. The bogie has bevel gearing in place of the worm gearing usually employed. In the 30-ton single axle, double epicyclic gearing is mounted in the wheel hubs.

A RECENT development of driving axles and bogies for heavy vehicles and earth-moving equipment is shown in the drawings reproduced herewith. They show a driving bogie employing hypoid bevel gears with a single epicyclic reduction in each hub designed for a load of 24 tons on the two driving axles and a single axle, shown on this page, designed to take the torque, approaching 800 lb-ft, of the latest automotive diesel engines and a load of 30 tons. Both units have been recently introduced by the Kirkstall Forge Engineering, Ltd., Leeds.

Double Hypoid Drive Bogie

Reference is made first to the double hypoid drive bogie, illustrated on pages 520 and 522. For many years most vehicles fitted with double drive bogies have used axles incorporating worm gears, as with a worm drive it is a simple matter to extend the foremost worm shaft to provide a through drive to the rearmost axle. These units have generally been extremely satisfactory but there has recently been a demand for double drive bogies incorporating bevel gears, owing to the fact that such gears have a higher efficiency at slow speeds than worm gears.

Various attempts have been made to produce a satisfactory arrangement, all of which necessitated a separate drive to each axle thus introducing a cardan shaft layout of some complexity. To overcome these difficulties an arrangement of bevel gearing has been adopted enabling a straight through drive to be taken from the foremost axle to the rearmost.

Hypoid gears are fitted and advantage is taken of the normal offset of the hypoid pinion to enable a drive shaft, omitted in the drawing, to pass over the normal axle shafts to transmit the drive to the rearmost axle. A good, rigid mounting for the hypoid gears is provided and the normal third differential introduced by the company many years ago is incorporated. The third differential can be replaced by a solid drive if required but much better tyre mileage is obtained when the third differential is fitted.

A 3·5 : 1 reduction provided by concentric gears in the hubs is not shown in our illustrations. Each wheel hub is mounted on cylindrical roller and ball bearings (approximately 8 13/16 in centres), the arrangement ensuring absolute concentricity to the hub gears. The races are secured to sleeves tapered on the axle casing, the latter being forged and externally stepped down to 4in diameter at the hub. The inner race has balls 1 1/16 in diameter. On the end of the 1 1/16 in diameter drive shaft are splines to receive a twenty-tooth sun wheel which engages with planetary gears of twenty-four teeth each. These are mounted from a spider shrunk on the axle, which also seats externally the wheel outer roller bearings. The annular gear has seventy teeth and forms the outer case of the wheel hub, to which it is secured by studs. The brakes are 16½in diameter by 6in wide.

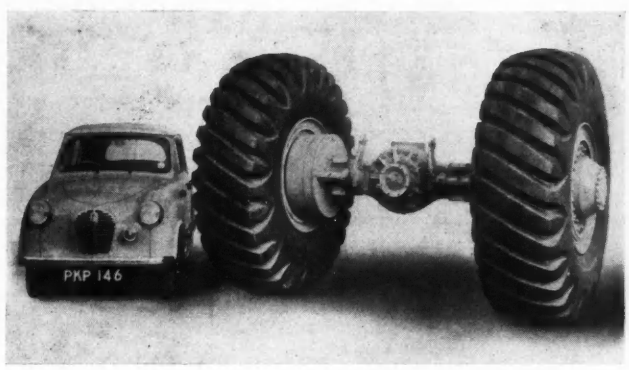
The bogie suspension arrangement is very similar to that used on the existing Kirkstall worm-driven bogies. The springs are provided with 3½in ball trunnions, allowing free articulation without twisting the springs. The bogie has been designed to suit a load on the two driving axles of 24 tons. 12·00×24in tyres can be fitted with an overall width of 8ft 1½in. Other tyre equipment can be fitted to suit special requirements.

30-ton Driving Axle

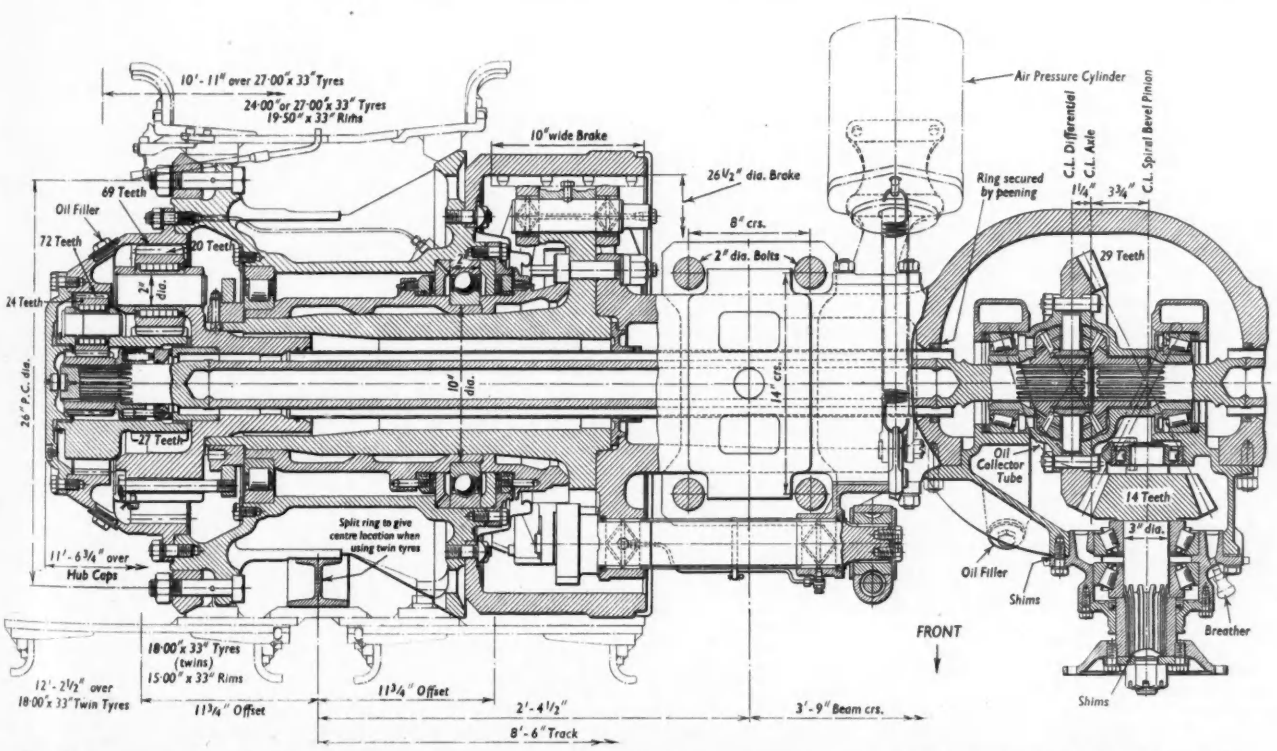
The 30-ton driving axle the company has developed is intended specifically for vehicles in the earth-moving category and those transporting large indivisible loads. It has been designed also to transmit torques of the order of 800 lb-ft, which are now available from automotive diesel engines, and to develop a tractive effort equivalent to ten double-decker buses. As earth-moving vehicles are operated under particularly arduous conditions and maintenance in the field is a difficult problem, a principle consideration in the design of the axle has been to render the wearing parts as accessible as possible.

In order to give the required tractive effort it was considered necessary to cover a range of ratios from 22 to 32 : 1. Such a big reduction could not be incorporated in the axle centre without making a gear assembly of complicated construction and enormous size and it was decided to effect as much reduction as possible in the hubs. It is an advantage also to have a small axle centre in order to obtain the maximum ground and body clearance, and a small differential assembly is also much easier to handle when it is necessary to carry out repairs when away from the vehicles' base work shop.

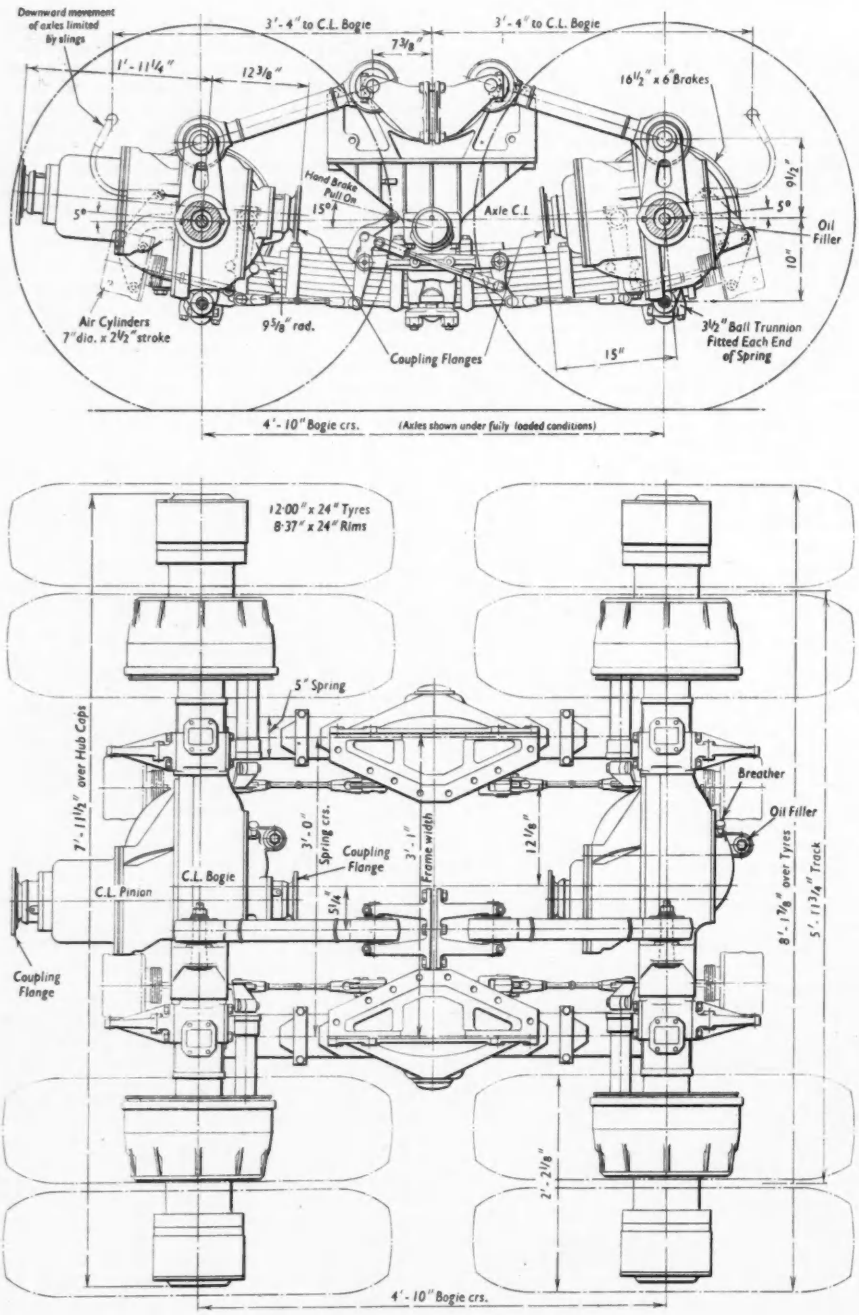
The reduction in the hubs is 13·22 : 1 and the reduction in the centre varies approximately from 1·6 to 2·4. This modest reduction enables a small-diameter crown wheel to be used allowing a very rigid mounting to be provided for the gears and the whole unit can be housed in a



30-ton axle with 13·22 : 1 compound epicyclic reduction gear in the hubs



General arrangement of single 30-ton axle, showing the compound epicyclic reduction gearing in the hub, and the small proportions of the differential gear



General arrangement of the 24-ton bogie

casing of very moderate size. The big reduction in the hubs has been obtained by using a two-stage reduction consisting of two sets of planetary gears.

It will be noted from the layout drawing that hollow axle shafts are used as a precaution against vibration and whirling problems which, due to the transfer of reduction to the hubs, might attend the relatively high axle speeds. To assist the fabrication of the axles, the solid ends are flash butt welded to the tubular section. The outer end is splined to receive the primary sun wheel, the spider of this stage being integral with the sun wheel of the secondary reduction train. The spider of this train is located by internal splines in the bore of the forged axle arm. Both the annular gears are integral with the hub casing. The numbers of teeth on each gear are marked on the drawing and as the reactions of the primary and final reduction trains are in the same direction, with both trains doing useful work, the final set of gears is smaller than would be otherwise possible.

As with the bogie axles, to ensure proper alignment of the planetary gears, each hub is mounted on one cylindrical roller bearing and one ball bearing. It is pointed out that on such a big unit the hubs themselves are heavy and difficult to handle and the task of starting the bearings on the axle arm becomes awkward. Consequently the bearings are mounted on a separate sleeve. This arrangement enables the whole of the hub units to be built up completely away from the vehicle, the assembly problem being very much simplified as the sleeve is easily pushed over the tapered axle arm. Similarly, the whole of this gear assembly can be removed without disturbing the road wheels or without jacking up the vehicle.

Special oil-sealing arrangements can be noted to prevent the oil from the hub gears getting into the differential assembly and vice versa. The hub gears and the outer hub bearings are lubricated with gear oil and to prevent any lubricant getting on to the brakes the inner bearing is lubricated by grease. Special face oil seals are provided to prevent oil from the hub gears getting into the bearings and also to prevent grease leaking on to the brakes.

The brakes are 26½in in diameter by 10in wide ; the brake linings being ¾in thick. Worm adjusters on the brake levers enable the whole of the brake lining thickness to be utilised. The axle is arranged to suit 24·00 or 27·00×33in single tyres or alternatively twin tyres 18·00 or 15·00×33in.

Telephone Branch Exchange at London Airport

A PRIVATE automatic branch exchange which will ultimately provide 1300 extensions is being installed in the new headquarters of the British Overseas Airways Corporation at London Airport.

This installation has been specially designed to provide speedy communication between London Airport and other airports, as well as direct contact with passenger termini and other offices in a more flexible manner than was previously practicable.

The exchange, known as a "PABX No. 3," was manufactured and installed by the Automatic Telephone and Electric Company, Ltd., Strowger House, 8, Arundel Street, London, W.C.2. It has ninety-five exchange lines and sixty private wires, and it provides a number of new facilities, of which perhaps the most important is a "hold for inquiry" facility. This enables users to hold an incoming exchange call and to make, at the same time on the same telephone, a further call to either an external or internal line. When this second or subsidiary call is completed it is a simple matter to restore the original call by merely pressing a button. To avoid the necessity for "flashing" in order to recall the operator, and so risking loss of the call, "operator recall" buttons have been fitted on the telephones.

Of particular importance is the facility which allows outgoing exchange calls up to a call fee value of sixpence to be made from all extensions. In this way operators are relieved of a considerable amount of traffic and are able to concentrate their attention largely on incoming calls. Special equipment ensures that all projected trunk and toll calls over sixpence are automatically referred to the operator.

Supervision is exercised over fire alarm calls, so that if for any reason a call to the fire station is not answered by the people on duty, any operator can immediately cut-in on the line, take the message and relay it as required.

In addition to the fourteen-position manual switchboard there is a special position for the supervisor which enables her to have complete supervision over the operators and at the same time to listen in at any time to any operator in order to give help or to prevent calls going unanswered.

To assist further in the smooth working of the switchboard, a special inquiry desk has also been installed. This allows calls to be correctly routed when a caller is unable to state the department which he requires. The value of the inquiry clerks has already been shown, for since the exchange opened they have dealt with an average of 400 inquiries daily.

Indoor Temperature Control

AN electronic control equipment for maintaining the temperature inside a building at any desired value is being marketed under the name of "Electronic Variator" by the Thermo Control Instrument Company, Ltd., 2–10, Valentine Place, Blackfriars Road, London, S.E.1.

The variator consists of an outside temperature detection element, water temperature immersion element and the central control unit. The sensing elements are thermistors, which have a very small heat capacity and therefore react quickly to changes in temperature. They also provide a non-linear characteristic which is of advantage in this application.

The sensing elements, together with other resistances, form an a.c. bridge network, the out-of-balance current from which is fed to the primary of a step-up transformer. The secondary voltage is applied to the grid of a double triode, each anode circuit containing one of the two windings of a balance relay which, in turn, energises a reversible valve motor to regulate the fuel or hot water supply. The firm states that the instrument will maintain the flow temperature to within ±1 deg. Fah. The system has also been incorporated in a zoning control arrangement whereby up to twelve detector elements are connected to the relay in sequence, each of which can be set to any temperature within the design range.

Mechanised Foundry for Flexible Working

The use of special mechanised equipment, compact flow moulding systems, a foundation grid designed in conjunction with standardised equipment footings which renders the plant layout flexible, together with the welfare amenities provided, combine to make the Tame Bridge Foundry of W. and T. Avery, Ltd. one of the most modern of its kind in Europe.

A HIGHLY mechanised foundry embodying many aspects of American practice and layout is now in production at Tame Bridge, near Walsall. It has been built for W. and T. Avery, Ltd., after several years' research and investigation into the latest mechanical foundry aids now or likely to be developed. It retains sufficient flexibility to deal with a range of iron castings weighing from 3 cwt to 10 tons. Two continuous cupolas are used on alternate days and their output can be as high as 320 tons per week.

Apart from the development in this country and the importing of several other outstanding items of foundry equipment, a notable collaboration has been effected in the design of the installations themselves and the layout of the foundations to receive them. The foundry substructure has been built as a grid in which a basic unit forming a given floor area and capable of supporting a given load is repeated throughout the various bays. All the machines and equipment in the foundry have been designed to conform with this basic grid and consequently any later redispositioning of the equipment or duplication of certain installations to suit any future flow pattern can be cheaply and quickly accommodated.

A further manifestation of the foresight exercised in the construction of this foundry is the provision made for the welfare of foundry workers. Apart from generous natural and artificial lighting, a forced air ventilation system and a pleasing colour scheme in the workbays, one of the most well-fitted amenities block of any in the country has been provided. It includes washing, showering and bathing facilities, heated lockers and is air conditioned. This block is placed at the front of the foundry, adjacent to the cafe and general offices. The company hopes by this means to counter the harmful social and physiological factors which have rendered the foundry trades bereft of skilled workers.

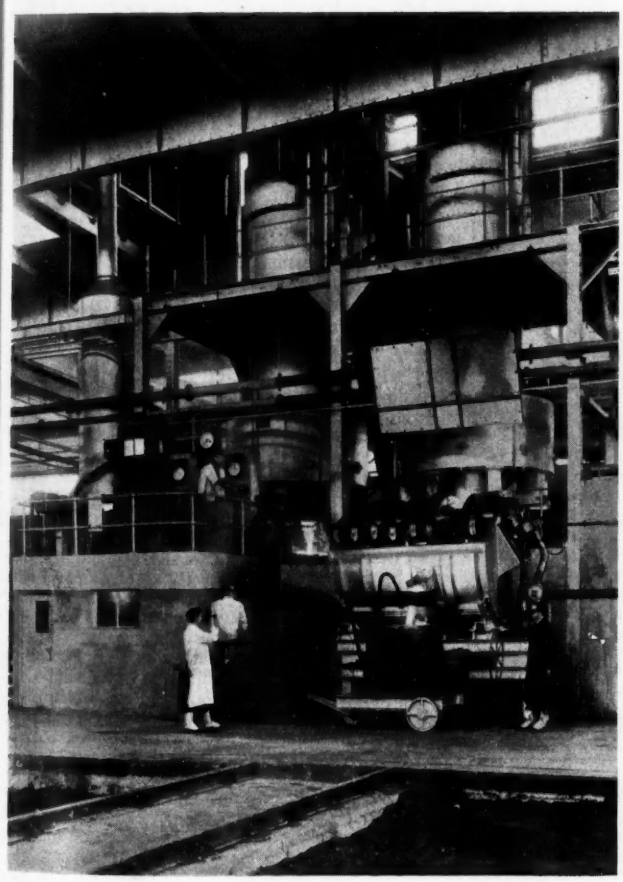
A model of the foundry showing the layout is illustrated on page 524. It will be seen to have four open bays, whilst a fifth divided from these is largely occupied by the administration and amenity blocks. The building is steel-framed and has a flat roof, which incorporates a generous monitored light system which is not shown on the model. The foundry encloses 167,000 square feet and the total cost has amounted to £1,250,000. The combined mechanical sand reclamation, reconditioning and distribution installations which form a considerable portion of the foundry's equipment are of special interest. A number of self-contained installations are disposed strategically in the foundry, and their design has been greatly influenced by the need to base them in accordance with the foundation grid. This requirement accounts to a large extent for the compactness and vertical development of these plants, which can be appreciated from our illustration of the heavy sand unit. A minor disadvantage it imposes is some crowding of the gangways, which can be noted.

Core-Making Plant

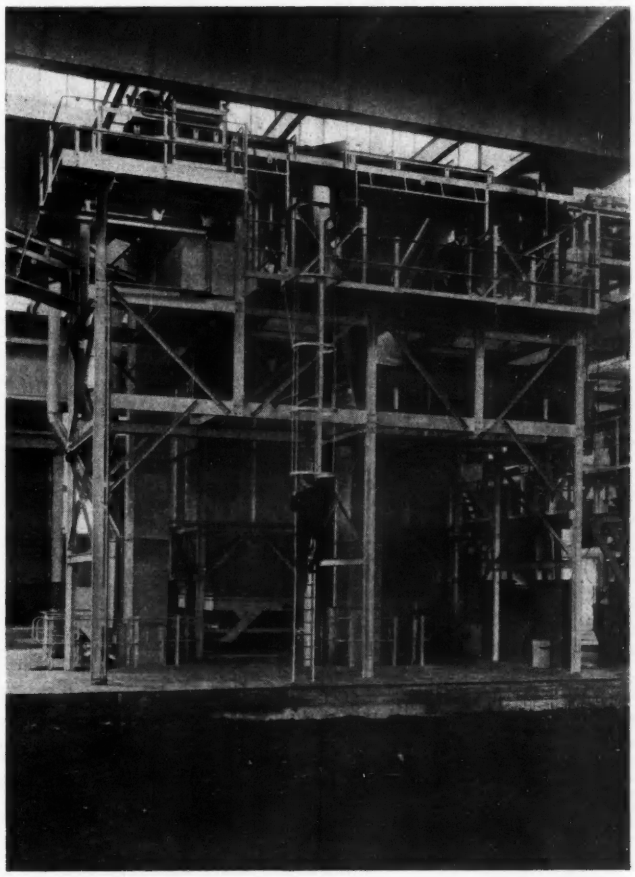
In a recent visit to this foundry our tour started in the core-making section, which occupies one corner. Silica sand is dumped in a pit of 300 tons capacity, and passes automatically, according to the demand, via conveyors and bucket elevators to a rotary drier of 1½ tons capacity. The rate of flow is determined by the water content of the sand. It passes from this installation through overhead pipes to a central mixing hopper serving the core-making benches. It is induced to flow there by a cyclone generator situated near the hopper, and in transit the sand is cooled. In the mixing hopper molasses, linseed and other core-making ingredients are added and the mixture is then pumped from the hopper to various airblown core-making units — made by J. W. Jackman and Co., Ltd.—grouped around it. Oil core-drying stoves of the latest design are also grouped at this station, various core-making and surface dusting stations being served by short roller conveyors. The ovens are equipped with variable speed processing equipment to accommodate the drying times of different cores.

Cupolas

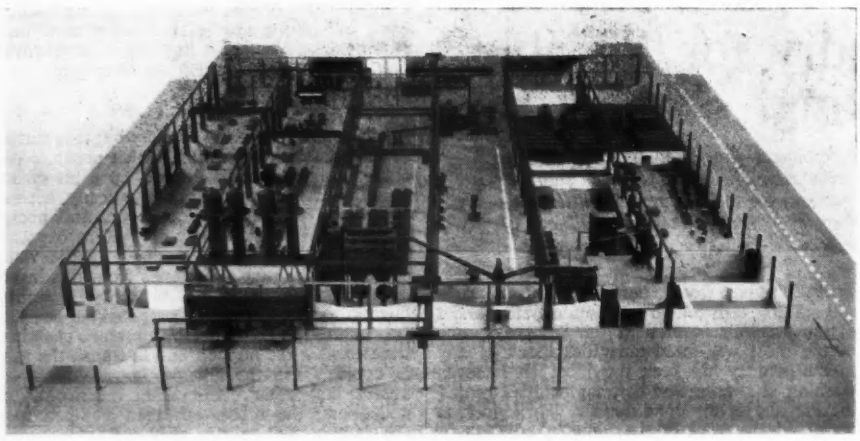
The position and layout of the cupolas and their charging bins is shown in our illustration. There are two continuous flow cupolas of American Whiting design and made in this country by the Incandescent Heat Company, Ltd. Each is in use on alternate days, the melting rate being 9 tons per hour. Pig iron, ferrous scrap, coke, and limestone are loaded through weigh-hoppers into a cylindrical drop-bottom bucket at floor level, which in turn discharges into the charge bucket which is elevated to the furnace. Molten metal from the cupola is tapped into an oil-fired container from which it



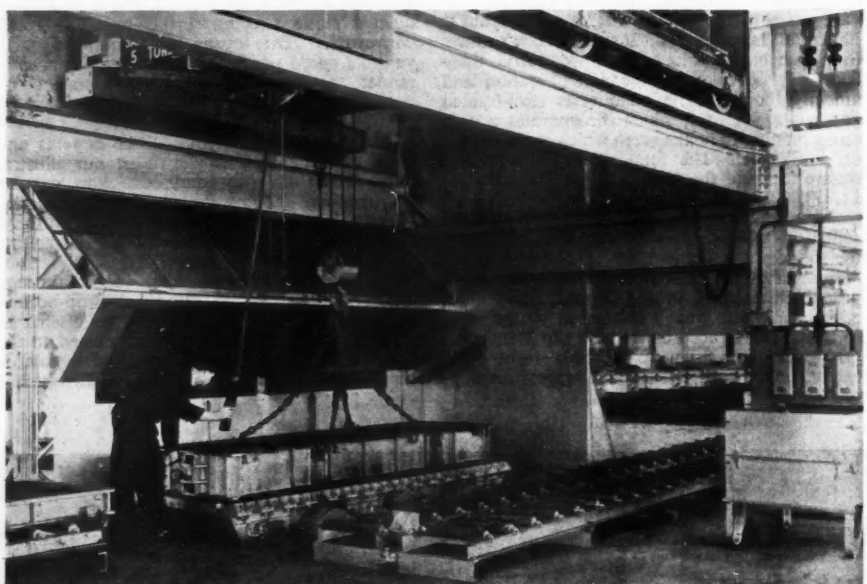
Twin continuous cupolas used on alternate days with the oil-fired holding vessel and control platform in the foreground



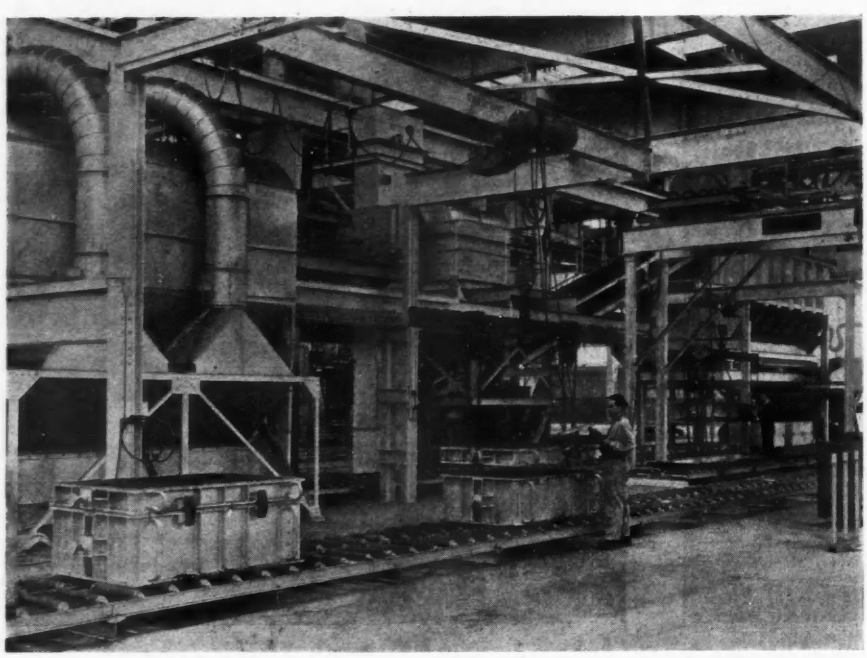
Heavy sand plant for motive sand slinger incorporating "shake-down" magnetic separator, rotary coolers, twin hoppers, vibrators and paddle mixers



Model of the foundry showing layout of bays and equipment



"Shake-down" plant which can recover up to 3½ tons of sand in 12 seconds



Some of the operations on the closed roller circuit serving the medium sized castings bay

is drawn off as required. The furnaces are equipped with the latest kind of dust arrester, the washing plant using 142 gallons of water a minute.

Heavy Moulding Bay

A single piece of equipment, the development of which seems largely to have determined the layout of much of the factory, is a mobile mechanical mould ramming machine or sand-slinger, It is an American development made by the Beardsley and Piper Company of Chicago, and was imported by Foundry Plant and Machinery, Ltd., Glasgow, being one of three employed in this country. The machine is driven on rails laid between two bays and it carries a 15-ton supply of sand. It has a cantilevered arm so articulated and actuated that the operator, seated at the outer end of the arm, has, through a joy stick, three-dimensional control of the sand discharge head mounted below him.

The flexibility of the moulding system made possible by this machine needs no emphasis. The arm can reach over practically the full width of both bays, so that mould boxes can be placed anywhere in these two bays without being beyond reach of the sand slinger. Movement of the machine along the rails is also controlled from the station at the end of the arm. Sand is pumped from the supply hopper to the discharging impeller at very high velocities at a rate of 2000 lb a minute. The impeller is driven by a 75 h.p. motor. The control provides, however, for lower discharge velocities required in the initial moulding operation when the pattern is bare. With a medium-sized casting the machine takes about one-sixth of the time normally required by manual ramming methods.

Heavy Sand Plant

The heavy sand plant which feeds this machine is shown in another of our illustrations. It can handle up to 45 tons of sand an hour and was made by The Coleman-Wallwork Co., Ltd.

After stripping, mould boxes are placed on a vibrating platform capable of taking boxes of 20ft by 10ft size, and containing up to 3½ tons of sand. Twelve seconds is sufficiently long to shake the hot sand from the box, which then drops through the platform grid on to a conveyor, the first of several conveyors and bucket elevators, on which the recovered sand and reconditioned sand automatically progress up and around the installation. To prevent fine particles from polluting the foundry atmosphere draught fans with a capacity of 16,000 cubic feet per minute are installed above the bed. Apart from the hoppers the plant includes a magnetic separator, two rotary coolers, vibrators, and paddle mixers, and provision is made to reject sand too fine or coarse from the throughput.

Medium Casting Bay

In the third bay of the factory an equally notable moulding system has been laid out for smaller castings of up to 12ft by 4ft. In this bay the moulding sequence is broken down into seven major operations which take place at fixed stations in a closed and compact circuit served by a ring of roller conveyors.

Much of the equipment of this system was made by Paterson-Hughes Engineering Co., Ltd. After casting the boxes are stripped and passed to the shake-out bed, which is part of a smaller sand reconditioning plant similar to that described. The patterns themselves are secured to plates and pass with the moulding boxes to a stationary sand slinger smaller but similar in principle to the American machine. This machine can discharge up to 800 lb of sand a minute. Each box is skimmed and passes to a stripping station where the pattern and its plate are removed, this process being assisted by a vibratory attachment. Our illustration shows in the foreground these latter operations and most of the roller track circuit can be seen. Subsequently the mould is closed and the metal poured and the cycle repeated after cooling. The system can cope with forty castings a day and its application to this size of casting is the outcome of an experimental installation made at the company's Soho foundry about five years ago.

Annual Report of the Gas Council

THE fifth annual report of the Gas Council which was published this week shows that during the year ended March 31st last, the sales of gas in this country totalled 2513 million therms, of which 26 per cent was sold to industry. More than 27,000,000 tons of coal were used in gas-making and the average yield of gas per ton of coal carbonised was 74·5 therms. In this connection it is interesting to note that since 1948 the efficiency of production at gas works has been improved from 71 to 75·2 per cent as a result of improved methods of working, replacement of obsolete plant and the closing down of small and uneconomic plants. Of the gas made at works 2009·8 million therms were coal gas, nearly 358 million therms were water gas and 27·6 million therms other gas. Gas obtained from other sources included 348 million therms from coke ovens, and 4·7 million therms from oil refineries. The report points out that the feasibility of the industry's taking supplies of "tail" gases from oil refineries is a complex question involving not only economic points but also the extent to which continuity of supplies over a satisfactory period could be guaranteed.

During the year under review the total manufacturing capacity of the industry rose from 11,374,800 therms a day to 11,552,100 therms, an increase of 1·4 per cent. The majority of this increase was in carburetted water gas, producer gas and oil gas plant; but the net increase of 7,000,000 cubic feet in carbonising plant is after allowing for the scrapping of plant to the capacity of some 60,000,000 cubic feet and its replacement by modern installations.

Two new important works brought into commission during the year were at Swan Village, Birmingham, and Maelor, near Wrexham. The first of these works augments the capacity of the old works by 11,000,000 cubic feet a day, and the second has a capacity of 2·25 million cubic feet a day. At the Portslade Works, Brighton, of the South Eastern Gas Board, a reconstruction which amounts almost to a new works is the 15,000,000 cubic feet a day capacity continuous vertical retort installation, the first section of which came into production last winter. The East Midlands Board brought into operation during the year the first section of reconstructed horizontal retorts at Grimethorpe Works, Sheffield; installations of continuous vertical retorts at Derby and Lincoln; and carburetted water gas plants to a total capacity of 5·15 million cubic feet a day at four other works. Carburetted water gas plants also figure prominently in the additions of the North Thames Board, three with a combined daily capacity of 12,000,000 cubic feet having been put to work at Southall. The further addition of 12·5 million cubic feet a day of continuous vertical retort capacity at Kensal Green and Bromley, less the plant of 5,000,000 cubic feet a day capacity which has been shut down during the year, brings the total rated capacity of the North Thames Board to 393 million cubic feet a day. Amongst the plant taken out of commission by this Board there was one of the first large-scale commercial continuous vertical retort installations to be operated in the country.

The North Western Board brought plant with a daily capacity of 15·85 million cubic feet into commission during the year. This board's plant at the Partington Station, Manchester, includes a recent installation of continuous vertical retorts consisting of two benches each of sixteen 82in retorts and each having a capacity of 2,000,000 cubic feet a day. One of these benches has been converted in order that trials on a commercial scale may be made of a process, developed experimentally in the Rochdale Station; it is designed to increase the throughput of coal by the introduction of a carrier gas at the bases of the retorts.

The report gives general details of the plant under construction at the works of the various area boards.

In Scotland the main gas making projects are concerned with future supplies of gas to Edinburgh and the Glasgow area. The former city is being provided with two continuous vertical retort installations, each of 4·5 million cubic feet a day capacity. The needs of Glasgow are being met mainly in three of the works there, especially at Provan, where large-scale reconstruction and additions to the plant are being undertaken. But they are also to be met in part by the big expansion at Dumbarton, where plant giving an additional capacity of 6,000,000 cubic feet a day was brought near completion.

Among constructional projects in the Northern Area is a 3,000,000 cubic feet a day carburetted water gas plant at Sunderland, the foundations for which have been laid. The North Western Board has twelve units with a combined capacity of 39·5 million cubic feet a day under construction. Nearly half the capacity of plant which the North Eastern Board has under construction is represented by the second installation of 7,000,000 cubic feet a day intermittent vertical chamber ovens at Tingley, due to be completed in 1955. Major projects of the East Midlands Board upon which work is proceeding include the erection of intermittent vertical chamber ovens of 8,000,000 cubic feet a day capacity at Car House Works, Rotherham; the reconstruction of the second section of horizontal retorts at Sheffield (Grimethorpe Works), together with coal and coke handling plant; and the second and third installations of continuous vertical retorts each of 5,000,000 cubic feet daily capacity at Derby (Litchurch Works).

The West Midlands Board has plant with a total capacity of approximately 61·5 million cubic feet a day under construction or authorised. Plant with a total daily capacity of 66·5 million cubic feet was either built or authorised by the North Thames Board during the year. The South Western Board has under construction carbonising plant with a total daily capacity of 17·7 million cubic feet.

The improvement in supplies of cast iron pipes enabled considerable progress to be made with main laying programmes, and during the year the length of mains in service increased by over 2300 miles to a total of 83,427 miles. This has enabled the extension of the grid systems linking works in all parts of the country and the consequent closing of small, less economic, plants.

On the coke and by-products side of the industry the sales of coke during the year totalled 10,600,000 tons, and breeze 1,500,000 tons, crude tar 1,445,000 tons, sulphate of ammonia 82,700 tons, spent oxide 266,600 tons, and crude benzole 27,772,000 tons.

The number of consumers of gas in this country increased during the year to 12,474,818, of whom 11,517,159 were domestic consumers. The average income per therm of gas sold was 16·39 pence; the average cost being 18·28 and 18·83 pence for domestic consumers, 12·20 pence for industrial consumers and 16·32 pence for commercial consumers.

The financial returns show that the industry had a net surplus, after transfers to and from taxation reserves, of £2,111,536 at the end of the year. Nine of the area boards had a surplus and three—the Scottish, Eastern and South Eastern Boards—a deficit on the year's working. The gross revenue of the industry was £297·4 million, of which £170·1 million came from sales of gas and £83·1 million from disposal of by-products.

Books Received

Electronic Measuring Instruments. By E. H. W. Banner. London: Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 45s.

The English Windmill. By Rex Wailes. London: Routledge and Kegan Paul, Ltd., Broadway House, 68–74, Carter Lane, E.C.4. Price 35s.

Engineering Analysis. By D. W. Ver Planck and B. R. Teare, jun. London: Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 48s.

Letter to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

FRENCH LOCOMOTIVE EXPERIENCES

SIR,—Before any other consideration, let me thank you very much for all these fine issues of "THE ENGINEER" you kindly sent me. I was very sensible of such courtesy, each of them being accompanied by your compliments. I have read with keen interest Mr. Livesay's "French Locomotive Experiences" and I have finally decided to write to you my comments upon them—in spite of my English which I suppose to be rather far from Shakespearean! So I'll try to say all that I think of these articles "in my own words." I beg you to excuse my treating your language so badly. Not myself alone, but other officials of the S.N.C.F. have read Mr. Livesay's articles and I am sure they would agree with my appraisal, but I am afraid few of them would take the trouble to say what they think. One of the reasons why I interested myself so much in these experiences, is I was a modest actor in a part of the whole affair. I had in fact the pleasure to be called to attend Mr. Livesay on the engines of the Northern Region to which I at present belong. All the articles are most interesting, even to uninformed people (I mean readers who do not care for railway technics).

I want to say more. These articles would deserve being translated into French, to give French readers not only the point of view of a competent foreign observer, but modern and complete information concerning the motive power of their railways. I know nothing so complete, so objective and vivid among all that has been written concerning our railways. Of course, we have many books and reviews about them, but these are either "hard to read, cold descriptions," or sketchy newspaper articles.

The great interest that "stands out" from Mr. Livesay's experiences is—for the reader—that it makes one feel he was a "very actor" who lived the whole action, and the reader can easily imagine being constantly beside Mr. Livesay—as I so often was! There was no mistake important enough to make it worth while correcting—he will be glad to hear this, as I know how anxious he was, when writing to me on this point, from far away Victoria, Canada—and directing me to show him no mercy!

I am sure everyone who read these articles now loves "U1" as Mr. Livesay does, and can imagine this engine running so sweetly—as he described—through this fascinating railway land. By the way, he will be glad to know that "she" is well and has just come from hoisting. She awaits him! Mr. Livesay is so understanding and so kind a man that he soon made many friends among us. I myself told him, a few days only after his arrival in France, "When I met you at Calais before getting on the 'Golden Arrow' engine, you were our guest: now, you are our friend!" and these were the very words that were in my heart. He smiled his pleasure, and I know he would not have appreciated merely flattering words.

He is back in France again, and I was very happy to meet him once more at Calais. For the second time, we had a fine run on the "Golden Arrow" engine and both of us thought that the clock has been set back. Everybody who learnt to know him is ready to welcome him again, and I am sure that together we shall do good work both for railways and for "l'Entente Cordiale"!

B. F. FILLON

St. Ouen (Seine),
France.
September 23rd.

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SULPHUR IN FUELS

Sulphur, except in the form of industrial acid or when used in other forms for industrial purposes, is an almost unmitigated nuisance. To the public at large its most obviously deleterious action is that which arises out of air pollution. Quite apart from those effects upon health, which the great London fog of December, 1952, emphasised, the damage done annually in one way and another by air pollution has been estimated to lie between £100 and £200 million, a large fraction of which must be debited against the sulphur compounds in the atmosphere. But for technical reasons the gas industry, the iron and steel industry, glass-makers, and manufacturers and operators of steam and internal combustion power plants all regard the presence of sulphur in fuels with disfavour. In the gas industry, by legal compulsion, hydrogen sulphide must be removed from the gas before distribution. Some 150,000 tons of sulphur are thus recovered from the gas each year. But the process is uneconomic. In blast-furnaces sulphur from the coke is transferred to the pig iron and has to be removed in the steel-making furnaces. Traces of sulphur in glass produce an unwanted yellow coloration, so that in glass production care has to be taken to eliminate the unwanted material. In power stations sulphur from the coal or oil fuel is deposited as sulphate on heating surfaces and boiler efficiency is further limited by the need to maintain economiser temperatures above dewpoint lest sulphuric acid be deposited on the tubes with resultant rapid corrosion. It is sulphur acids that seem primarily responsible for rapid cylinder wear in petrol engines subjected to frequent starting and stopping. Yet paradoxically, this material, whose presence is so unwelcome to every user of fuel, has in recent years tended to be in short supply for industrial use in the making of acid and for other purposes.

It is possible that in arranging a conference on the removal and recovery of sulphur from fuels, one paper from which we reprint on another page, the Institute of Fuel had primarily in mind the reduction of air pollution. In fact, however, the tendency of the papers presented at the conference was to study the removal of sulphur for quite other reasons and to concentrate upon its recovery, rather than merely its removal, in order to meet this country's need for an indigenous supply of sulphur. Nor, incidentally, was the study confined rigidly to fuels; other raw materials, particularly for iron and steel-making, were also studied. At present, industrial usage of sulphur in the United Kingdom is running at a rate of about 350,000 tons per year, of which about 25,000 tons per year come from home sources, mainly from the gas industry and oil refineries. The remainder is imported, principally from the United States, at a cost of about £4,000,000 per annum. Yet in the 205 million tons of coal consumed annually in this country there are some 3,000,000 tons of sulphur, and the Middle East oil, which predominates in our oil supplies, is also, unfortunately, rich in sulphur, averaging 2·2 per cent. Furthermore, world demand for sulphur since the war has tended to outrun supply, and is also tending rapidly to increase. It has been, for instance, estimated—though very tentatively—that the demand of this country alone may very nearly double within twenty years. The known reserves of brimstone in America are not large and, though further sources will no doubt be discovered, there is no certainty that sufficient will be found to meet the world's mounting demands. Everything thus favours the recovery of sulphur from fuels. Fuel-using industries would benefit by the elimination of an obnoxious element; sulphur-using industries would benefit by an assured supply. One thing alone stands in the way. None of the methods of recovery is fully established as economic and most, including the method primarily used by the gas industry, are definitely uneconomic. Mere removal, as in gas-washing plants at Bankside and Battersea power stations in London, adds as much as 10s. a ton to the fuel costs, and gives a product of no saleable value whatever. Moreover, its efficacy, even as an expensive means of preventing damage by air pollution, is open to question.

By organising the conference the Institute of Fuel has undoubtedly served a very useful purpose. The existing situation can now be appreciated far better than before. But it is not a very encouraging one, despite the amount of experiment and development that is being done. It is true that in the treatment of gas for sulphur recovery there are a number of processes, particularly wet processes, in use or under trial, that promise to be or are beginning to prove themselves to be economic, even without making allowances for the improvement in the performance of other plant, as in steelworks, that may follow from sulphur removal. But the bulk of the fuel used in this country is solid or liquid. There the situation appears to be far less satisfactory. Where sulphur occurs in coal in the form of discrete particles or masses of pyrites it can be removed, probably economically. But a substantial fraction of the total sulphur, dependent upon the nature of the seam, will appear as finely disseminated pyrites and organic sulphur. No proved method of removal is known. Furthermore, there is a probability that the sulphur content of British coals will rise as the years pass. Coke contains about the same percentage by weight of sulphur as the coal from which it was made, and little progress seems to have been made towards finding a large-scale method of desulphurisation. As for oil, only about 10 per cent of its sulphur content can at present be recovered, and though lighter fractions can be and are produced more or less sulphur-free, the bulk of the sulphur is retained in the residual fuel oils. Thus, fuel-burning users, except those using gas or the lighter oils, cannot look forward to a time in the foreseeable future when their fuels will be sulphur-free, nor even, with any confidence, to a drop in the percentage sulphur content. The conclusion in earlier editorial comment this year that in attempting to reduce air pollution a problem very difficult to solve is posed by the sulphur dioxide in flue gases is thus further reinforced.

NEW METHODS OF LIFESAVING FROM SUBMARINES

It is over fifty years ago since the first submarine was commissioned for service in the Royal Navy, but the real hazards facing men who try to escape from a sunken submarine were not fully understood until the Second World War when the practicability of operating midget submarines and human torpedoes was investigated. Down to the late twenties the only hope of saving life lay in salvage. In 1912 bulkheads were fitted dividing the submarine into three or four watertight compartments. It was assumed that not all the compartments would be flooded, and that some of the crew would be able to gather either in the fore or

after end which might then be brought to the surface in reasonably shallow water. This actually happened on one occasion during the first world war, when "K13" sank in the Gareloch while doing her acceptance trials. The circumstances were, however, quite exceptional. The water was shallow, there was no tide and, most important of all, the accident was observed by another submarine which immediately gave the alarm. The entire resources of the Clyde shipyards were at once set in motion, the fore end was raised within two days and the forty-eight men entombed there were saved. Under normal conditions when there are currents and spells of bad weather, salvage may take several days or even weeks. It was finally abandoned in 1929 as a means of saving life.

In that year, as a result of trials, it was decided to provide each man in a submarine with a Davis submarine escape apparatus—an adaptation of a breathing apparatus used in mines, tanks, &c., where foul air may be expected. The wearer breathes into a bag in which is a canister containing a chemical for absorbing the carbon dioxide exhaled and which is supplied with pure oxygen from a cylinder at a pressure equal to that of the surrounding water, thus enabling him to breathe in a normal manner. The men don the apparatus and flood the compartment through a valve, until the air remaining is compressed to the pressure of the depth of water, when the escape hatch can be opened. To prevent it closing again immediately when the first large bubble of air rushes out (thus making the sea pressure overhead momentarily greater) a twill trunk is fitted to each hatch and "stopped up," out of the way, when not in use. When the trunk is let down in an emergency, the small amount of air entrapped in it after the compartment is flooded up is released through a valve and the hatch is opened without difficulty and remains open. Each man in turn steps under and inside the trunk and rises to the surface. This has remained the standard method of escape up to the present day. Research, however, has proved that the main hazard is not, as might well be supposed, the ascent. Several men have come to the surface without any breathing apparatus at all. The dangerous period occurs while the compartment is being flooded and the men are waiting to escape. It has been found that a man may be liable to oxygen poisoning after breathing oxygen for five minutes from his Davis apparatus. On the other hand, if he delays donning his apparatus once the compartment starts to flood, he faces two other equally serious dangers. If the submarine has been diving for some hours the air will be foul from carbon dioxide. A match barely remains alight. This can be endured provided the pressure approximates to that of the atmosphere. But carbon dioxide poisoning sets in after a very short time when the compartment starts to flood at a depth of 150ft with consequent compression. The second danger is the 79 per cent of nitrogen in the air. If this is breathed for long under pressure, nitrogen accumulates in the blood and, when released suddenly by a quick ascent to the surface, causes "bends" or divers' paralysis. New methods of saving life have, therefore, been devised, based on two principles. First, "free ascent" is better than ascent with a Davis apparatus. By taking a deep breath a man has ample air to last him to the surface. Indeed, the weight of air in his lungs under 100ft water pressure is about three times what it is on the surface and he must breathe out hard to get rid of the surplus as he rises. The second principle is that escape gear must not be fitted at the cost of good military characteristics, which are the main protection against casualties through enemy action—the cause of the overwhelming majority of submarine disasters.

Existing submarines are to be fitted with extra valves to quicken up flooding. Also, built into the ship at each end, bottles of a mixture of oxygen and nitrogen with a tube and mouthpiece are to be installed for each man to breathe while flooding up. In new submarines, space will be made available at each end of the vessel for a one-man escape chamber, its hatches and valves being operated from the compartment. The crew will thus continue to breathe air at atmospheric pressure until each man's turn comes to enter the chamber. In less than a minute the chamber will be flooded and the man will have reached the surface. New submarines will also have bulkheads strong enough to stand the pressure at any depth to which the submarine can dive and the one-man chamber will be fitted to take a rescue (diving) bell lowered down from a rescue ship. This will enable escapes to be made at depths of over 300ft. New submarines will have air supply and exhaust connections to enable the air to be refreshed while waiting for the rescue vessel or in case of suspension of operations by bad weather. Finally, all submarines, existing and new, are to be fitted fore and aft with radio indicator buoys, under water telephones and signal ejectors and the crews are to be supplied with immersion suits to keep them afloat and comfortable on the surface.

Obituary

AIR CHIEF MARSHAL SIR RODERIC HILL, K.C.B.

WE record with regret the death of Air Chief Marshal Sir Roderic Hill, K.C.B., F.R.Ae.S., which occurred suddenly, in London, on October 6th. Sir Roderic, who was sixty, had spent a distinguished career in the scientific branches of the Royal Air Force, and, since his retirement from that service in 1948, had been Rector of the Imperial College of Science and Technology.

Roderic Maxwell Hill, who was the son of Professor M. J. M. Hill, of London University, was educated at Bradfield College and at University College, London, of which he was subsequently elected a Fellow. In the early part of the first world war he served in the 12th Northumberland Fusiliers, transferring to the Royal Flying Corps in 1916. After a year's service in France with No. 60 Squadron, Sir Roderic was appointed to take charge of the experimental flying department at the Royal Aircraft Establishment, Farnborough. He remained there for six years, his work being recognised by the award of the A.F.C. and Bar. Sir Roderic initiated a number of experiments concerned with the radio control of aircraft, and with the investigation of wing flutter. He received the R. M. Groves Memorial Prize in 1921. Sir Roderic left Farnborough in 1923 and in the following year graduated at the Royal Air Force staff college at Andover. Thereafter he served for a time with the technical staff at the Middle East headquarters, returning to this country in 1927 to become an instructor at the R.A.F. staff college.

Sir Roderic Hill, K.C.B.

In 1932, Sir Roderic was appointed deputy director of repairs at the Air Ministry, and in 1936 again went overseas for two years as Air Officer Commanding in Palestine and Transjordan. In 1938 he returned to the Air Ministry as director of technical development.

During the second world war, Sir Roderic held several important appointments. He was director-general of research and development in the Ministry of Aircraft Production during the critical period of the Battle of Britain, and then went to Washington with the British Air Commission as controller of technical services. Sir Roderic next became Commandant of the R.A.F. staff college, and in the summer of 1944, when the flying bomb attacks on this country had to be countered, he was appointed commander-in-chief of Fighter Command. At the end of 1946, Sir Roderic was placed in charge of a new department of the Air Ministry which became responsible for all branches of the technical work of the Royal Air Force. At the same time he was promoted to the rank of Air Chief Marshal. From 1946 until his retirement in 1948, Sir Roderic was Principal Air Aide-de-Camp to H.M. King George VI. He was created C.B. in 1941 and promoted to the honour of K.C.B. in 1944. In addition to his services as Rector of the Imperial College during the last six years, Sir Roderic was last year elected Vice-Chancellor of the University of London. On account of failing health, however, he felt compelled to relinquish that office a few months ago.

RUTHERFORD MEMORIAL LECTURES.—The council of the Royal Society has appointed Professor M. L. E. Oliphant, F.R.S., of the Australian National University, to be the Rutherford Memorial Lecturer for 1955. Professor Oliphant will deliver lectures in India and Pakistan.

Brunswick Wharf Power Station

Brunswick Wharf power station was officially opened by Lord Citrine, chairman of the British Electricity Authority, on Wednesday, October 6th. The station first began operation on March 26, 1952, and is designed for an ultimate capacity of 330MW, generated by four 52·5MW and two 60MW turbo-alternator sets. Initial steam conditions are 900 lb per square inch and 900 deg. Fah. and twelve 320,000 lb per hour boilers will eventually be installed.

THE site of Brunswick Wharf power station extends over approximately 19 acres near the north end of Blackwall Tunnel, Poplar. Constructed in the old East India Dock, the station building itself occupies slightly more than two-thirds of the dock area of about 8 acres. The remainder, which has a deep-water frontage of 850ft on the River Thames, is used for coal storage. One-third of the coal stock is under water in order to prevent spontaneous ignition of the pile. The mechanical and electrical workshops and the stores building are along the west boundary, and the coal-handling plant workshop and store building is arranged conveniently to the plant it serves. The 132kV switch house and transformer parks are placed at the north of the main station building, and a welfare building is provided. The power station is shown in the various illustrations herewith.

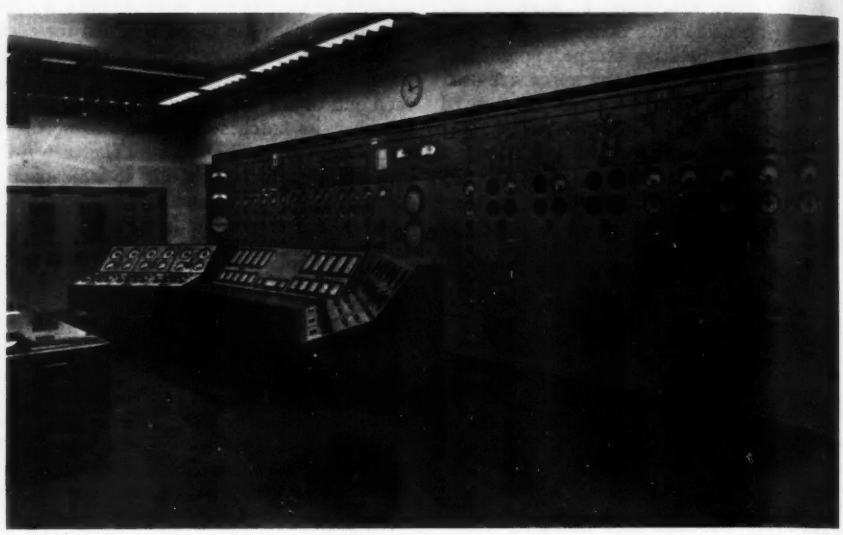
Constructional Details

The foundations of the station are spread bases resting on London blue clay, which is found at 9ft below the bottom of the dock or 47ft below the level of the quay. The chimney foundations are each 75ft square and 14ft 6in thick. Reinforced concrete walls enclose the basement and incorporate on the north and west sides the 66in diameter circulating water pipes. The south retaining wall is of parabolic section and carries the north rail track of the transporter bridge, while the other end of the 220ft bridge span runs on rails supported by 60ft precast reinforced concrete piles driven into the clay. On the suspended roadway to the south of the station are built the brick-clad, concrete bunkers for dust and ash. The river front has been equipped with a rail track, a roadway and a track for three (eventually four) coal offloading cranes.

The wharf deck consists of an 8in slab carried on reinforced concrete beams, which are supported at the river face on 18in square precast concrete king piles spaced at 12ft centres, with 18in by 12in precast concrete sheet piles between. These are finished with a capping beam held back by 2in diameter steel ties spaced at 24ft centres and anchored into pile caps mounted on groups of raking piles driven into the clay at the back of the existing river wall. A 17ft wide strip was gained by filling the space between the old and new river walls with mass concrete. The river at the wharf has been dredged and a chalk bed has been deposited so that colliers can be moored alongside at any state of the tide.

The disused entrance lock to the dock was dammed at both ends and filled with rubble, and is used as an emergency storage area for ash.

The smaller buildings to the north of the station (the switch house, transformer park and welfare building) rest on 14in square precast concrete piles set in the Thames ballast which overlies the London clay.



Control room, showing control desk and panels

Generating Plant

The four 52·5MW turbo-alternators and the two 60MW turbo sets are arranged along the axis of the 730ft long turbine room. Originally all the sets were to have been of 52·5MW capacity, but Nos 5 and 6 were increased in 1948 to the present size, giving a total capacity of 330MW.

Turbines.—Each turbine has three cylinders with eleven impulse stages in the high-pressure cylinder. The 52·5MW turbines have fourteen intermediate stages, and four in each half of the double-flow low-pressure cylinder, while the 60MW turbines have thirteen and five stages respectively. The last low-pressure stage in each case is effected by two sets of nozzles and two impulse wheels.

Initial steam conditions are 900 lb per square inch and 900 deg. Fah., and there are five stages of feed heating, with two boiler feed pumps between the third and fourth stage. At maximum continuous rating the final condensate temperature is 365 deg. Fah. for the 52·5MW turbines and 380 deg. Fah. for the 60MW turbines.

In addition to the twelve electrically driven feed pumps there are two steam-driven standby sets, one for each group of three turbines. The pumps for the 52·5MW turbines have an hourly capacity of 500,000 lb; those for the larger turbines are driven by 1300 h.p. squirrel-cage motors and can deliver up to 575,000 lb per hour. De-aeration, apart from that taking place in the condenser, is effected in the third feed heating stage.

The designed steam and heat consumptions per kilowatt-hour are, for the smaller turbines, 8·433 lb and 9390 B.Th.U. at full load, and 8·604 lb and 9869·5 B.Th.U. at 60 per cent of full load; for the larger turbines these figures are 8·4839 lb and 9310·6 B.Th.U. at full load and 8·5179 lb and 9493·6 B.Th.U. at 60 per cent of full load.

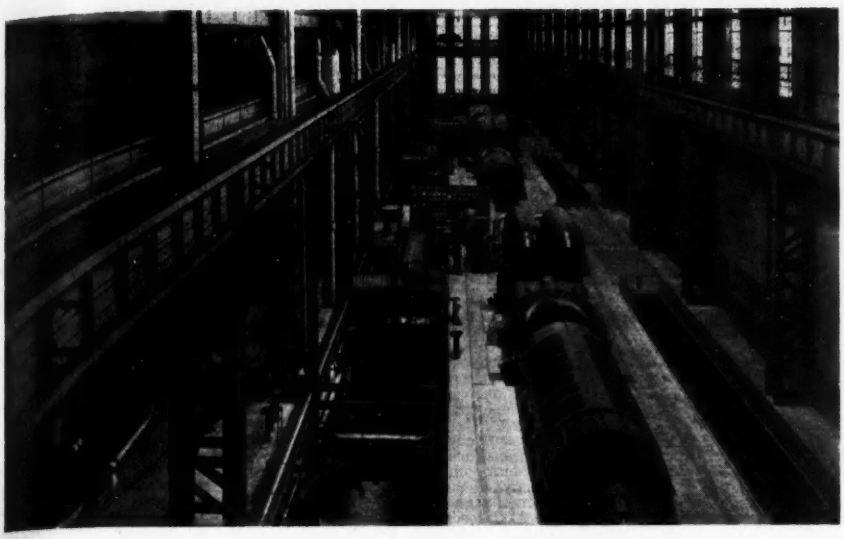
Condensers.—Twin condensers with a total cooling surface of 48,000 square feet are provided for each set. With cooling water at 55 deg. Fah. and a vacuum of 29in Hg. (30in Hg barometer) the condensers of each of the smaller turbines are designed to deal with up to 333,000 lb of exhaust steam per hour. There are two condensate extraction pumps per set, each of 790 gallons per minute capacity.

The condensers of the 60MW turbines are designed to condense 375,000 lb of steam per hour with cooling water at 54 deg. Fah. and a vacuum of 28·9in Hg (30in Hg barometer).

Condenser Circulating Water System

The intake and the outfall works are built integrally with the jetty and wharf and are connected to the condensers on the inlet side by four cast iron pipes, and on the outlet side by two reinforced concrete culverts. At the west end of the jetty, water is taken in through debris screens to ten screen chambers. Each chamber is equipped with a 48in travelling band screen and controlled on the river side by a 6ft by 5ft electrically operated penstock, and on the clean water side by a similar 10ft by 3ft penstock. The

Brunswick Wharf power station from north-west



Turbine house looking west, showing three 52·5MW sets

flow from each group of five screens goes to a common pump suction chamber, and two chambers below ground level for the pumps themselves. Each of the eight vertical spindle circulating pumps has a 40in diameter suction and a 35in discharge, and is driven by a 300 h.p. motor to pump up to 32,000 gallons per minute.

The water leaving the condensers is taken to the outfall in two reinforced concrete culverts, each 6ft. wide and 9ft. 6in. high. These can be isolated from the river by four electrically operated 8ft by 8ft penstocks.

Central Evaporating Plant

In the turbine room, between Nos. 3 and 4 sets, is the central evaporating plant, which is designed for operation by steam at 900 lb per square inch and 900 deg. Fah. It is fed with water supplied by a base exchange lime/soda softener plant, and has an output of 80,000 lb of distillate per hour, with a dissolved oxygen content not exceeding 0·025 cubic centimetres per litre, a total solids content not exceeding 0·5 parts per 100,000, and a pH value of 8·5.

Steam Generating Plant

Each of the pulverised-fuel-fired boiler units is designed for an output of 320,000 lb of steam per hour at 925 lb per square inch and 925 deg. Fah. when supplied with feed water at 365 deg. Fah. The heating surfaces and other salient particulars of each boiler unit are as follows :—

Surface	Area	Square feet
Boiler parts	Super	8,200
Combustion chamber walls, excluding any boiler tubes	Projected	5,950
Economiser	Super	19,530
Superheater	Super	13,880
Air heater	Super	2×36,000
Furnace volume	24,063 cubic feet	

Coal consumption, at maximum continuous rating is 36,700 lb per hour for coals of 11,500 B.Th.U. per pound calorific value. The amount of heat released per cubic foot of combustion chamber is 17,500 B.Th.U. per hour. The design efficiency is 86·5 per cent at 265,000 lb per hour, and 86 per cent at 320,000 lb per hour.

Each boiler unit is equipped with three bowl-and-roller pulverising mills, each of 20,000 lb per hour capacity (at 10 per cent moisture), and having its own separate exhauster fan. The fuel is discharged to twelve tangential burners, arranged in groups of three at each corner of the combustion chamber. For starting up, and for low-load operation with poor coals, oil burners have been incorporated in these assemblies. The whole steam plant is automatically controlled.

Flue Gas Cleaning Plant and Chimneys

Before being discharged through the chimneys the flue gases undergo electrostatic precipitation. Switchgear, transformers and rotary rectifiers for the precipitators are housed in the 100ft chimney pedestals, which are steel-frame structures lined with brick. The flue gas ducting from the boilers enters the chimney at the upper level of this steelwork. The chimneys themselves are of reinforced concrete lined with acid-resisting brick, and stand 300ft above ground level.

Ash Disposal

Accumulated ash deposits from the combustion chambers are periodically entrained by high-pressure water jets. Dust from the economisers, air heaters, centrifugal dust collectors, and electrostatic precipitators, is handled dry. Belt conveyors discharge dust and ash to the storage plant at either end of the boiler-house south wall, from where dampened dust and ash is loaded on to road vehicles. In addition, the conveyors can discharge directly to a barge loading point.

Electrical Plant

Alternators.—The 52·5MW sets have directly coupled 61,765kVA directly excited alternators, which are totally enclosed and fan cooled. The 60MW sets have hydrogen-cooled, 75,000kVA alternators, also directly coupled and directly excited.

Step-Up Transformers.—The step-up transformers are in the outdoor park along the north wall of the station building. Each turbo-alternator set has its own transformer to which it is permanently connected. For the smaller sets, the transformers are of 55,500kVA capacity and 11·8/134kV ratio, while the larger sets each have a 72,000kVA, 11·8/141·6kV transformer. All have remote-control, on-load, tap-changing equipment.

Step-Down Transformers.—Each set is connected by removable links to a 5000kVA, 11·8/3·3kV transformer. These supply motors above 100 h.p. and are in the electrical auxiliaries annexe inside the building along the north wall of the turbine room, together with a number of 750kVA, 3·3/0·415kV transformers for supplying smaller motors. Other 750kVA, 3·3/0·415kV transformers are spaced throughout the plant near the groups of units which they serve.

Auxiliary plant is also supplied from two station transformers, each of 10,000kVA, ratio 132/3·3kV, which are supplied from the main busbars. These transformers are also in the transformer park.

Switchgear.—The 132kV switchgear is a duplicate busbar system incorporating double-break, resistance-shunted, air-blast units having a short circuit rating of 2,500,000kVA. The building housing this switchgear is to the north of, and separate from, the main station building, and is provided with plant for the accurate control of temperature and humidity of the atmosphere within the building. The 3·3kV auxiliary switchgear is of air-break type and has a short circuit rating of 150,000kVA.

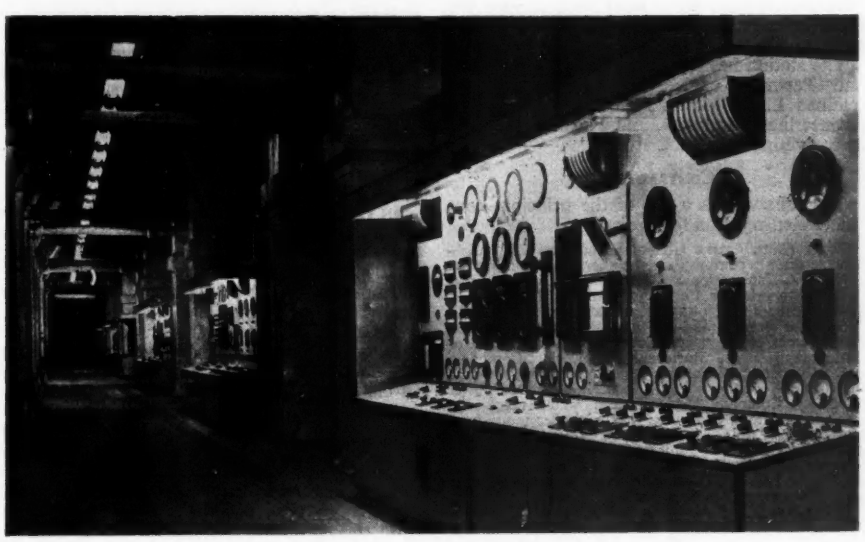
The 11·8kV cables between the stator of each generator and its respective main step-up and unit transformer are single core, paper insulated, lead covered. The 132kV cables between the main step-up transformers and the 132kV switchgear, the 132kV switchgear and the 10,000kVA station service transformers are single core, gas filled, lead covered. The 3·3kV cables are either single core, paper insulated, lead covered, or three core paper insulated, lead covered, wire armoured. In addition, mineral insulated copper sheathed cables have been utilised extensively throughout the station for the smaller power and control circuits.

Coal Handling Plant

Coal arriving by seagoing collier is unloaded by three—ultimately four—jetty cranes, on to an 800 tons per hour conveyor belt system which delivers it either directly to the boiler-house, or to the storage area. From storage, coal is transferred to boiler bunkers with at least forty-eight hours' capacity. The storage area is spanned by a travelling bridge, which has on its lower chord a belt conveyor for discharging coal to storage, and on its upper chord a reclaiming conveyor which is loaded from two 100-ton reclaiming cranes situated on the bridge.

Buildings

The power station building and subsidiary buildings are of steel-framed construction, clad



Boiler house aisle, showing boiler control panels

with 13½in brickwork except the welfare building, which has a frame of reinforced concrete.

Due to the length of the main power station building, two expansion joints have been incorporated which divide the building into three separate sections. External walls are faced with Southwater bricks, which are light golden brown in colour, while plinths and other prominent brickwork are in dark brown Blockley wire cuts. Internal walls are in Flettons. Artificial stone with a Portland stone finish has been used for the surrounds of the main entrances, whilst thresholds have been constructed in York stone. External walls incorporate large windows of steel-frame construction ; those to the precipitator bay and turbine room have electrically operated opening sections. Large lantern lights are incorporated in the roofs of all main bays.

All floors are of granolithic concrete, laid on concrete slabs, except in the case of the turbine room, where terrazzo tiles with matching surrounds to the machinery beds are used. The walls of the turbine room are lined with 24in by 12in faience tiles fixed vertically without break joints.

The 132kV switch house is also steel framed and brick filled. In this building the walls are of 15½in cavity construction and double glazing has also been incorporated to reduce heat losses in cold weather. The roofs of the switch house, administration and accommodation blocks and the mechanical and electrical workshops and stores are insulated with a 3in layer of Vermiculite.

The administration block is developed, architecturally, on conventional lines. This building accommodates the various offices, control, meter, telecommunications and battery rooms.

In determining the layout of the plant assemblies in the station, one of the major considerations was the provision of ease of access for operation, inspection, maintenance and repair. Wherever possible, therefore, staircases, at 45 deg., instead of ladders, are provided, and all staircases and walkways have a minimum width of 2ft with a minimum headroom of 7ft. To facilitate maintenance and repair, runways to carry travelling lifting tackle have been provided in the main building steelwork over all major items of auxiliary equipment and in the case of the boiler plant fan floor a "jubilee" track has been provided for the handling of fan motors and fan runners. Further, to all major levels, clear access ways of ample width and headroom, extending to the length of the station, have been incorporated to facilitate the transport of equipment to or from the loading bays.

Other items of equipment include automatic fire-protection equipment to safeguard against fires affecting transformers, cables and turbine lubricating oil systems ; the "Precipitron" air filtration and plenum ventilation system for the control, telecommunications and meters rooms; and the central calorifier heating installation supplied with reduced pressure steam from the main steam generating units and serving the administration block, 132kV switch house, workshops and welfare building.

The station has been designed by John Bruce and Partners, engineering consultants, who retained L. G. Mouchel and Partners as civil engineering consultants, and Farmer and Dark as consulting architects.

Contractors

The following is a list of the principal contractors engaged on the project :—

Boiler plant, Clarke Chapman and Co., Ltd. Sub-contractors : combustion chamber and combustion equipment, International Combustion, Ltd. ; superheaters, Superheater Company, Ltd. ; economisers, Senior Economizers, Ltd. ; air heaters, induced draught and forced draught fans, "Centicell" dust extraction plant, James Howden and Co., (Land) Ltd. ; electrostatic precipitators, Sturtevant Engineering Company, Ltd. ; concrete casing for electro-static precipitators, Bierrum and Partners, Ltd. ; sootblowers, Ivor Power Speciality Company, Ltd. ; feed water regulators, Copes Regulators, Ltd. ; valves and boiler mountings, Hopkinson, Ltd. ; integral high-pressure pipework, Aiton and Co., Ltd. ; automatic boiler control, Bailey Meters and Controls, Ltd. ; air compressors, Broom and Wade, Ltd. ; oil fuel equipment, Wallsend Slipway and Engineering Company, Ltd.

Turbo-Alternator plant, Sets Nos. 1 to 6, Metropolitan-Vickers Electrical Company, Ltd. Sub-contractor : C.W. and boiler feed pumps, Mather and Platt, Ltd.

Central Evaporating plant and circulating water piping, Aiton and Co., Ltd. ; high-pressure and low-pressure pipework, C. A. Parsons and Co., Ltd. ; low-pressure pipework (No. 6 set), Brightside Foundry and Engineering Company, Ltd. ; coal-handling plant, International Combustion, Ltd. ; sub-contractors : belting, India Rubber, Gutta Percha and Telegraph Works Company, Ltd. ; travelling bridge, Fraser and Chalmers, Ltd.

Cranes, jetty and travelling bridge, Stothert and Pitt, Ltd. ; turbine room (120/15-ton), Cowans, Sheldon and Co., Ltd. ; (40/15-ton), Wharton Crane and Hoist Company, Ltd. ; feed pump bay, 15-ton, Cowans, Sheldon and Co., Ltd. ; mechanical and electrical workshops, Herbert Morris, Ltd. ; circulating water pump house, Wharton Crane and Hoist Company, Ltd. ; mill hoists, Vaughan Crane Company, Ltd. ; switch-house hoists and trolley, Geo. W. King, Ltd.

Water Softening plant, Permutit Company, Ltd. ; ash and dust handling plant, Babcock and Wilcox, Ltd. ; ash and dust disposal plant, International Combustion, Ltd. ; compressors, Reavell and Co., Ltd., and Broom and Wade, Ltd. ; vacuum cleaning plant, Sturtevant Engineering Company, Ltd. ; circulating water-screening plant, F. W. Brackett and Co., Ltd. ; locomotive, Robert Stephenson and Hawthorns, Ltd. ; chlorination plant, Wallace and Tiernan, Ltd. ; low-tension switchgear, English Electric Company, Ltd. ; high-tension switchgear, English Electric Company, Ltd. ; extra high-tension switchgear, British Thomson-Houston Company, Ltd. ; reactors, British Thomson-Houston Company, Ltd. ; transformers (main), Metropolitan-Vickers Electrical Company, Ltd. ; (auxiliary), Johnson and Phillips, Ltd. ; cables, London Electricity Board, Aberdare Cables, Ltd., British Insulated Callender's Cables, Ltd., Pirelli-General Cable Works, Ltd., Standard Telephones and Cables, Ltd.; lighting, (all internal and external lighting excluding switch house), London Electricity Board ; (switch house, first half), Johnson and Tanner ; (switch house, second half), Troughton and Young, Ltd. ; batteries, Edison Swan Electric Company, Ltd. ; battery charging equipment, English Electric Company, Ltd. ; telephones, Standard Telephones and Cables, Ltd. ; lifts (main station and mechanical and electrical workshops), Keighley Lifts, Ltd. ; (canteen), Marryatt and Scott, Ltd. ; heating and ventilating installation, G. N. Haden and Sons, Ltd. ; wharf, circulating water pump house foundations, circulating water intakes and outlets, Marples, Ridgeway and Partners, Ltd. ; coal-handling plant foundations, Marples, Ridgeway and Partners, Ltd. ; main and ancillary building foundations and coal store, Peter Lind and Co., Ltd. ; buildings and internal furnishings, Peter Lind and Co., Ltd. ; reinforced concrete chimneys, Tileman and Co., Ltd. ; structural steelwork, Redpath, Brown and Co., Ltd. ; filtration plant, Sturtevant Engineering Co., Ltd. ; fire protection equipment, Mather and Platt, Ltd. ; canteen kitchen equipment, General Electric Company, Ltd. ; control room panels, British Thomson-Houston Company, Ltd.

Social and Industrial Consequences of the Presence of Sulphur in Fuels

No. I

By A. PARKER, C.B.E., D.Sc., F.Inst.F.*

We print below the opening paper presented at a conference organised by the Institute of Fuel and held in London on Wednesday and Thursday of last week. The conference was held for a "Special Study of Sulphur Removal and Recovery from Fuels." Here Dr. Parker reviews the general situation. British industry has so far been unable to obtain the necessary supplies of sulphur, sulphuric acid, carbon bisulphide and other compounds at reasonable cost from indigenous resources. Yet while we are dependent largely on imported sulphur in one form or another, the fuel and fuel-using industries are put to considerable expense in removing sulphur from fuels required for special purposes ; and great damage to structures and materials, health and agriculture is caused by the emission into the atmosphere of sulphur dioxide and trioxide from the combustion of the major quantities of fuels from which the sulphur is not removed and cannot economically be removed.

Introduction

In 1953 Great Britain used nearly 350,000 tons of sulphur as such, including about 253,000 tons for the manufacture of sulphuric acid and 95,000 tons for other purposes. Of this total, no more than about 25,000 tons was obtained from home oil refining and by extraction from spent oxide. The remainder, more than 300,000 tons, was imported, mainly from America, at a cost in dollars equivalent to about £4,000,000. In fact, our imports of brimstone in 1953 were only about 200,000 tons ; the additional amount used in that year was obtained by drawing on stocks from previous imports. Other sources of sulphur for the production of acid were 378,000 tons of imported pyrites and 174,000 tons of zinc concentrates, 286,000 tons of spent oxide from the purification of gas for public supply, and 183,000 tons of indigenous anhydrite. This means that in total we used about 750,000 tons of sulphur in one form or another, three-quarters of which was imported as sulphur or sulphides.

For certain purposes sulphur in almost pure form is necessary ; and the manufacture of sulphuric acid from brimstone has several advantages, including lower capital and labour costs, over the processes of manufacture from sulphides and anhydrite. But over many years we have been dependent for our supplies of brimstone on imports from America, where the amounts available to us are in turn dependent on the relationship between world demands and the productivity of a few sulphur domes in Texas and Louisiana, or the discovery of new resources as those now being exploited become exhausted. During recent years demand has exceeded supply and has led on occasion to considerable difficulty. These difficulties of supply are likely to recur ; and sulphur, sulphuric acid and other sulphur compounds are key materials for many industries. We must be ready, therefore, to make better and greater use of indigenous resources, including the recovery of relatively pure sulphur from fuels and other materials, as we have no natural deposits of brimstone. The costs of obtaining sulphur from indigenous resources are at present greater than the price of imported brimstone ; but we cannot afford to take a narrow and short-sighted view on costs in dealing with a key material.

Sulphur in Coal and its Products

As mined, British coals contain from less than 1 to 4 per cent or more of sulphur. Some of this sulphur, usually less than 1 per cent of the coal, occurs as natural organic constituents derived from the original vegetable matter from which the coal was formed. In addition, there are sulphates in finely disseminated minerals and deposits from infiltrated natural waters, finely disseminated pyrites, and interbanded or other strata of pyrites and other minerals necessarily brought up with the mined coal, particularly with mechanised mining. Much of the extraneous mineral matter can be separated by hand picking for the larger pieces and by systems of coal cleaning for the smaller sizes. In this way the sulphur content of the coal as mined can be and is reduced. It is not economically practicable, however, to remove the finely disseminated mineral matter, and there are no satisfactory methods of removing the sulphur inherent in the coal substance itself.

At the present time the average amount of sulphur in British coals as supplied to consumers is about 1·5 per cent. Improvements in methods of coal cleaning will increase the proportion of extraneous mineral matter that can be removed from the coal as mined ; but improvements in this direction are likely to be more than offset by increases in the amounts of extraneous matter and sulphur in the available coals, as the seams of coals of better quality are depleted and those of poorer quality have to be mined to maintain supplies. In general, therefore, the sulphur content of the coals available to consumers is likely to increase over the years.

Our annual coal production is now about 225 million tons, of which 205 million tons are consumed in this country. This quantity of 205 million tons contains a total of 3,000,000 tons of sulphur, which is roughly four times our consumption of sulphur for sulphuric acid and for other needs. Of this 3,000,000 tons, only 140,000 to 150,000 tons is recovered in the form of 280,000 to 290,000 tons of spent oxide from the purification of gas for public supply. The value of the spent oxide does not nearly cover the cost of purification of the gas, but the gas industry is under legal obligation to remove practically the whole of the sulphuretted hydrogen before the gas is distributed ; the legal limit for sulphuretted hydrogen in town gas is about 1½ parts per million.

Of the 205 million tons of coal consumed within the country, nearly 55,000,000 tons (or about one-quarter) are carbonised at coke ovens, gasworks, and some other works to produce coke, gas, tar and chemical by-products. Almost the whole of the remainder, totalling 150 million tons, is burnt direct for domestic heating, for raising steam, for generating electrical power and for various types of industrial furnaces.

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The weight of coke obtained on carbonising British coals is 60 to 70 per cent of the weight of the coal. As the percentage of sulphur, in general, is about the same in the coke as in the original coal, the total quantity of sulphur in the coke is 60 to 70 per cent of that in the coal. The remaining sulphur, 30 to 40 per cent, is mainly carried forward in the gas, most of which is purified, though large quantities of coke oven gas are still burnt unpurified for heating the ovens and for some other purposes.

Some of the coke made is used by the gas industry for making water gas for admixture and purification with coal gas for town supply. Large quantities are used in the iron and steel and other metallurgical industries as a reducing agent. In blast-furnaces much of the sulphur in the coke combines with the lime charged into the furnaces and is removed in the slag. More than one-half of the coke made, or roughly 20,000,000 tons a year, is burnt in boilers and other industrial furnaces and in domestic heating appliances.

Sulphur in Oils

With the rapid increase during recent years in the oil refining industry in Great Britain, we are now importing nearly 30,000,000 tons of petroleum oils a year, containing on average about 2 per cent of sulphur or a total of roughly 600,000 tons of sulphur. In the refining processes sulphur is now being recovered at the rate of about 30,000 tons a year.

Allowing for re-export, oils for ships' bunkers in foreign trade and shipping, losses in refining, &c., inland consumption of petroleum oils of all types is 17,000,000 or 18,000,000 tons a year. This includes about 5,000,000 tons of fuel and gas-diesel oils for boilers and other furnaces, 2,000,000 tons of diesel oil for road transport and other engines, 5,000,000 or 6,000,000 tons of motor and aviation spirit, nearly 2,000,000 tons of kerosene, rather more than 0·5 million tons of gas oil for gas manufacture, and more than 2,000,000 tons of industrial spirit, white spirit, lubricating oil, wax, bitumen, &c. The fuel oils on average contain 3 to 4 per cent of sulphur, diesel oil and gas oil 0·5 to 1 per cent, while motor and aviation spirit, kerosene, and other refined products contain very little sulphur. Our indigenous production of petroleum and shale oil is only about 150,000 tons a year.

In addition to petroleum oils, we use as fuel about 0·5 million tons a year of creosote-pitch containing about 1 per cent of sulphur, and 0·3 million tons of motor benzole and other spirit, with very little sulphur, from the carbonisation industries and from the hydrogenation of creosote.

Recovery of Sulphur from Fuels

As already mentioned, the coals consumed annually in Great Britain contain 3,000,000 tons of sulphur, and the imported oils contain 600,000 tons, making a total of 3·6 million tons a year, that is nearly five times our consumption of sulphur or six times the quantity imported as brimstone, pyrites and zinc concentrates. Of the total of 3·6 million tons, we recover at present only about 170,000 tons, mostly as spent oxide in the purification of gas for public supply and partly as sulphur in oil refining. These recovery processes are operated primarily to render the particular gaseous and liquid fuels more suitable for the purposes for which they are required, and partly to reduce pollution of the atmosphere from the use of the fuels. The value of the sulphur obtained does not meet the cost of the recovery processes.

During the 1939–45 war a special effort was made to recover pyrites from certain coals, to augment the supplies of imported pyrites for the production of sulphuric acid. Eight coal cleaning plants together produced about 20,000 tons a year of pyrites fines containing 42 per cent of sulphur, equivalent to 8000 tons of sulphur a year. Though pyrites fines from coal cleaning are not so suitable as imported pyrites for the manufacture of acid, they can be used without too much difficulty, particularly if mixed with imported ore. At the present time only three of the eight plants are in operation ; they produce annually about 6000 tons of pyrites fines, to which should be added 5000 tons of pyrites of larger size recovered from coal by hand picking. Attempts have been made to recover pyrites from pulverised coal by air elutriation and by the " fluidised solids " technique, but they have not so far shown signs of economic success.

It has long been known that sulphur can be removed from petroleum oils by hydrogenation under pressure. The method was used during World War II to give high yields of high-octane aviation spirit from certain fractions of petroleum oils. Latterly, variants of the liquid-phase hydrogenation treatments have been developed that convert most of the sulphur in distillate oils to hydrogen sulphide. For example, the Anglo-Iranian auto-fining process at Llandarcy treats about 500 tons of light oil a day, using little or no extraneous hydrogen, and the Shell Company is installing a somewhat similar process at Stanlow, based on by-product hydrogen.

The main impact of petroleum refining on sulphur recovery has resulted from the development of modern catalytic cracking, which releases 40 to 45 per cent of the sulphur in the cracking stock as hydrogen sulphide. In catalytic cracking in Great Britain at the present time about 60,000 tons of sulphur a year are thus released as hydrogen sulphide, which may be present in amounts up to 10 per cent in the gas from the cracking process. If the gas is to be used for polymerisation or synthesis of chemicals, or is to be sold for public supply, the hydrogen sulphide must be removed. If it is to be used for heating in the refinery, the gas need not be purified, though the recovery of the sulphur would be in the national interest, and might just be economic in the narrow sense. In the refineries in Great Britain at which catalytic cracking is practised, the hydrogen sulphide is removed from the gas by the Girbotol process, using solutions of diethanolamine to absorb the sulphide, which is afterwards liberated in concentrated form by steaming. The gas from the Girbotol plant contains 75 to 90 per cent of hydrogen sulphide, usually with a yield of at least 95 per cent. As already stated, about 30,000 tons of sulphur a year are now being produced in this way in Great Britain.

One difficult problem that has not been solved is to reduce at reasonable cost the sulphur content of residual fuel oils, which often contain 3 or 4 per cent of sulphur and sometimes more than 4 per cent. The sulphur can be removed by hydrogenation, but the amount of hydrogen required is so great as to make the cost of the process prohibitive.

Detrimental Effects of Sulphur in the Use of Fuels

There is no doubt that many of the problems and difficulties that arise in the preparation and use of fuels would be avoided if the natural fuels available did not contain sulphur. There are numerous instances in which the presence of sulphur reduces the maximum practicable efficiency of utilisation of the fuels and involves the adoption of more expensive processes and materials of construction than would otherwise be necessary. The papers to be presented later in this Special Study will deal with some of the difficulties and how they have been or might be overcome. It is not intended, therefore, in this paper to do more than refer briefly to some typical examples of the difficulties and detrimental effects due to sulphur in fuels.

Iron and Steel Industry.—Sulphur has an adverse effect on the properties of iron and steel. As most of the sulphur in the raw materials used in this industry is that in the coke used in the blast-furnaces, it is important that everything economically practicable should be done to obtain coke of comparatively low sulphur content. Almost the whole of the sulphur in the coke is retained in the slag and in the pig iron produced under the reducing conditions in the blast-furnace, and the blast-furnace gas obtained is practically free from sulphur. The relative distribution of the sulphur between the slag and the iron can be controlled to some extent by the amount of lime charged with the iron ore and coke. With larger quantities of lime more of the sulphur finally appears in the slag and less in the iron ; but the amount of slag and the consumption of coke for each ton of iron produced are thereby increased. It is usual, therefore, to specify an upper limit of some figure below 1 per cent for the sulphur in coke for blast-furnaces. This in turn means the selection of coking coal of low sulphur content for the production of the coke in coke ovens. As the supplies of good coking coals have been and are being depleted more rapidly than the supplies of other coals, the difficulties of obtaining good coking coal of low sulphur content are steadily increasing, and there is a tendency for a rise in the amount of sulphur in the coals available. In the future more attention will have to be given to the cleaning of coal for the production of coke for the metallurgical industries ; and there must be a compromise in assessing the suitability of the coke on the basis of the usual tests for sulphur, abradability and crushing strength. To ensure that sufficient coke of suitable quality will be available, there must also be an extension of the practice of blending coals for carbonisation in coke ovens.

With open-hearth furnaces one main object is to remove sulphur from the pig iron and scrap. This is achieved by maintaining a suitable slag, as in the blast-furnace, but most of the sulphur in this instance must escape as sulphur dioxide in the waste gases, otherwise there is an increase in the quantity of slag with a decrease in productivity and an increase in cost per ton of metal.

When fuels containing sulphur are used for reheating furnaces, in which steel ingots and billets are heated to the temperatures necessary for rolling and forging, some transfer of sulphur from the furnace gases to the steel is unavoidable. To keep down the amount of sulphur taken up by the steel it is usual to operate the furnace under such conditions as to produce a fairly heavy layer of scale on the steel. This results in a decrease in yield, with additional cost.

In those processes in which coke oven gas is the fuel, there is a prospect of removing 80 or 90 per cent of the sulphur from the gas at a cost that would be economic. With coal and coke as the fuels the limits are set by the costs of coal cleaning. With fuel oils there is no early prospect of developing a process that would remove a substantial proportion of the sulphur at reasonable cost, and the petroleum fuel oils available in this country have a high content of sulphur.

Glass Industry.—Another industry in which sulphur in the fuel can have a serious effect on the quality of the product is that of glass-making. Sulphur in the gases may be absorbed by the glass and cause yellow discoloration, and if the glass is at the annealing stage the product will become cloudy instead of remaining clear.

Steam Raising and Fuel Efficiency.—With the steady improvement in the efficiency with which fuels are used for raising steam and for other purposes, sulphur in the fuels has become an important limiting factor in efforts to effect further improvement in efficiency. It is also limiting the periods during which boilers and other furnaces can be operated continuously without shutting down for repairs and maintenance and for removal of troublesome deposits.

Modern power station boilers, for example, can be operated with coal and oil as fuels with overall thermal efficiencies of over 85 per cent. Considerable difficulty is often caused, however, by the deposition of sulphates and acid sulphates on the heating surfaces, particularly if the fuel contains unusually large amounts of sulphur and of alkali chlorides. The presence of sulphur also limits the extent to which heat can usually be recovered in the air heaters, as it raises the dewpoint of the waste gases, or that temperature at which the sulphur trioxide in the gases condenses as sulphuric acid and causes corrosion of the air heaters. The problems involved are of such importance that there has for some years been a Boiler Availability committee in this country guiding and undertaking investigations on the subject, in the laboratory and on a full scale at power stations. This committee, whose investigations have involved considerable expenditure, includes representatives of boiler-makers, the British Electricity Authority, the British Coal Utilisation Research Association, and the Fuel Research Station of the D.S.I.R.

Similar considerations are involved in efforts to improve the efficiency of use of fuels in other types of boilers and furnaces.

Domestic Heating.—Even with domestic heating appliances there is a limit of efficiency which

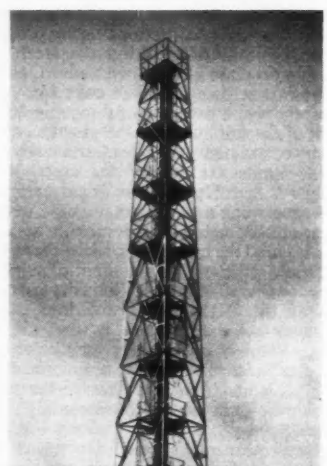
must not be exceeded with fuels containing sulphur if the temperature of the chimney gases is to be kept above that at which condensation of acid occurs, with consequent attack on the materials of construction of the chimney or flue pipe. There have been many instances in housing estates, particularly with domestic boiler flues exposed on outside walls to considerable cooling, in which the chimney flues have been badly attacked by acid condensates.

Internal Combustion Engines.—It is well known from experience that sulphur in fuels for internal combustion engines can cause serious corrosion of engine parts, particularly with frequent starting and stopping of the engine under conditions likely to lead to condensation of acid. To overcome this difficulty considerable expense is incurred in oil refining to provide fuels low in sulphur for internal combustion engines for road transport, aircraft and other purposes.

(*To be continued*)

Vertical Drawing of Thermometer Tubes

A 130FT high tube-drawing tower for the production of clinical thermometer tubing has been erected by Pirelli-General Cable Works, Ltd., at the Whitefriars glassworks of James Powell and Sons, Ltd., at Wealdstone. It is equipped with four drawing trolleys which, by means of wires, hoist the molten glass from four billets



Tube drawing tower with central chamber containing the four drawing trolleys

anchored at the foot of the tower. When a trolley has drawn the thermometer tubing to the required height, the operator, by means of electronic controls, regulates the trolley's drop in stages so that the tubing can be cut into canes of convenient length. Height and speed of the draw are controlled by electronic equipment and motors housed at the base of the tower, which is lit for night climbing and fitted with safety ladders. It is stated that the tower has improved the quality of the clinical thermometer tubing which was formerly produced at Whitefriars by means of the horizontal hand-drawn method.

Three-Dimensional Analogue Computer

The continuous development of radar and guided missiles has created a stream of complex mathematical problems and to solve some of the most difficult of them the Ministry of Supply is now bringing into operation at the Royal Aircraft Establishment a new electronic-hydraulic calculating machine or "simulator" called "Tridac." The name "Tridac" is derived from the phrase "three dimensional analogue computer."

THE biggest calculating machine in this country, and among the largest in the world, was recently demonstrated at the Royal Aircraft Establishment at Farnborough. A general view of the machine layout is given in our illustration. It occupies 6000 square feet of floor space, it uses 8000 valves, and under peak conditions it absorbs about 650kW from the supply mains. This machine, known as "Tridac," differs from most of the well-known large calculating machines in that it is an "analogue" machine, whereas the others, such as the "Ace" computer at the National Physical Laboratory, are "digital" machines. In a digital machine the quantities in the problem are represented by sets of electrical pulses, and the number and arrangement of the pulses in each set represent the value of one of the quantities. The machine is able to count these pulses very rapidly and to add sets of pulses and perform some other simple operations. It is provided with a programme which enables it to perform very complex calculations by breaking them down into a series of simpler operations, and it can do this very rapidly. In an analogue machine a voltage or shaft angle or other physical quantity varies continuously in proportion to the quantity it represents. Thus, one voltage might represent the forward speed of an aeroplane according to a prearranged scale of, say, 1V to 10 m.p.h., while a shaft angle might represent the altitude of the aircraft on a scale of, say, 1 deg. per 100ft. An analogue machine is in effect a working model of the system and it becomes especially useful when the model is set to work on a "real" or "unity" time scale so that events in the computer occur at the same time as in the real system. It is then possible to include actual equipment, such as the motor which moves the ailerons in an aeroplane with powered controls.

"Tridac" has been built on analogue rather than digital principles for the following reason. Digital machines can be programmed to carry out long series of operations in sequence, with great accuracy. However, with existing techniques, large numbers of operations cannot be carried out simultaneously (or sufficiently quickly when executed in sequence) so that in general an involved problem cannot be reproduced on a real time scale and thus the inclusion of parts of the real system in place of the machine calculation is not possible. It may be that in the future digital machines will operate more rapidly so that the construction of real time scale simulators of high inherent accuracy will be possible. At present, exclusive of consideration of the time taken for setting-up, programming, &c., certain problems which might be solved on a digital machine would take several hundred times longer in actual machine computation time than the same problems on "Tridac."

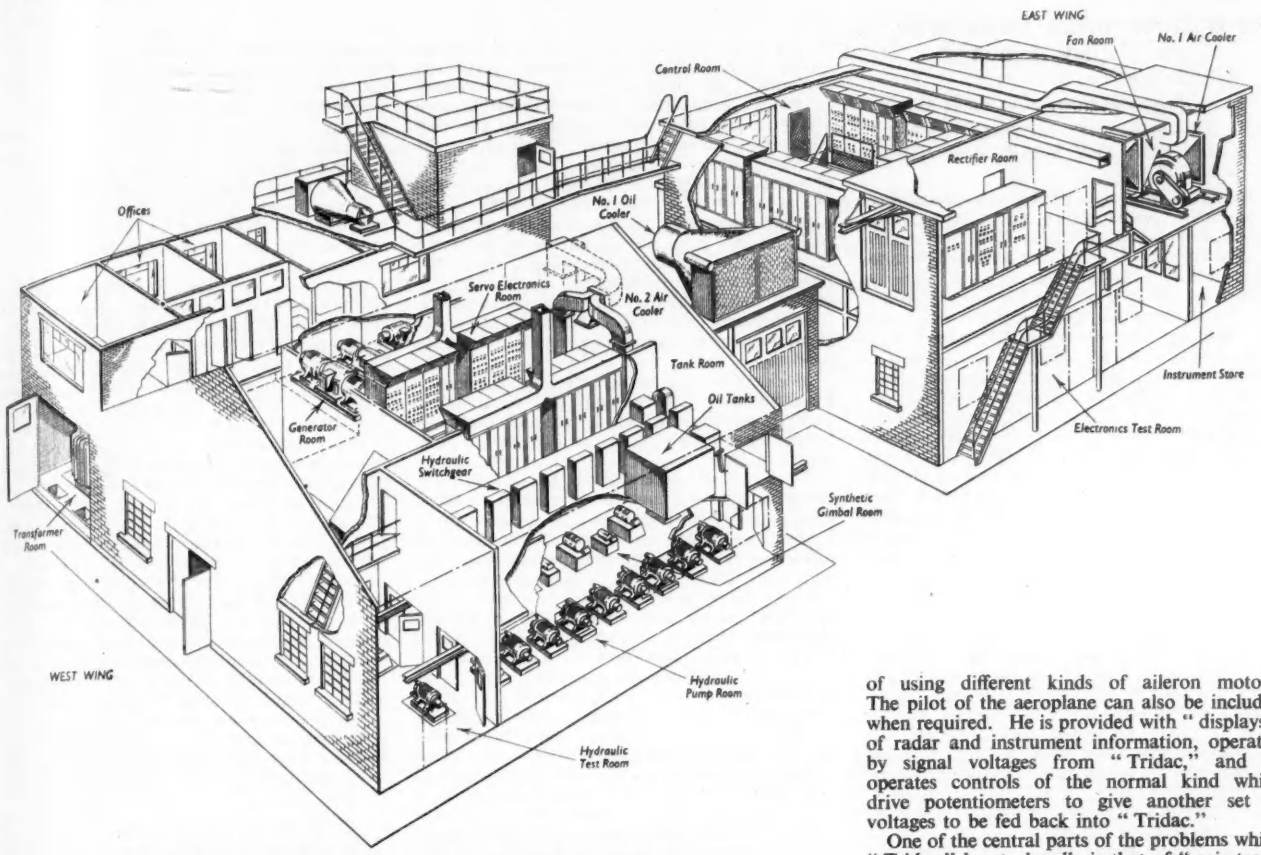
The machine is intended to serve as a research tool for the applied physicist, aerodynamicist and engineer, and the basic data available for most of the problems to be studied will rarely be known to better than 1 per cent accuracy, so that solutions with an error somewhat less than 1 per cent are adequate. In "Tridac" each individual mathematical operation is carried out with an error not greater than 0·1 per cent of full scale. The fact that an analogue machine of the "Tridac" type provides a working model of the system greatly assists the research worker to understand the system, and as such it may be regarded as an "aid to physics" or as an "aid to engineering." A digital machine is more usually an "aid to mathematics."

The basic analogue quantity in "Tridac" is a d.c. voltage and the basic element in the majority of the computing units is a high gain d.c. amplifier with input and feedback impedances arranged so as to give an overall transfer function corresponding, for example, to addition or integration. To avoid errors due to drift in the amplifiers each amplifier is stabilised by association with a separate drift-stabilising a.c. amplifier of either the mechanical-chopper or magnetic-modulator type. The gain of the basic d.c. amplifier is of the order of 60,000 and the drift stabilisers can confine the drift to within a few millivolts. All the amplifiers and similar units are built on small chassis (known as "bricks") of approximately 12in by 8in by 3·5in, which slide into arrays of pigeon-holes in the cabinets. There are forty-four cabinets containing in all about 2000 "bricks," of which approximately 600 are d.c. amplifiers, 350 are mechanical-chopper stabilisers and 250 are magnetic-modulator stabilisers. These and other electronic "bricks," for the operations of multiplication, division, resolution, curve generation, &c., can be interconnected in any required way by plug and socket boards.

Another major section of the computer is a group of nine electrically-controlled hydraulic servo motors. Each servo is provided with its own 35 h.p. electric motor and pump delivering oil at 2000 lb per square inch to the main hydraulic valves. A common low pressure pump supplies oil at 250 lb per square inch to the pilot valves. These high performance servos drive assays of potentiometers. There are about 224 such potentiometers, some of which are directly driven and some of which are driven through sine or cosine linkages. They may be used to multiply voltages appearing in the main electronic computation by the appropriate servo input or by the sine or cosine of the appropriate servo shaft angle, and many of them are used in the "axis transformation" calculations mentioned below.

A central generator room housing rotating machinery supplies power at various voltage levels and frequencies to the entire simulator. The supply voltages are accurately stabilised in individual voltage-stabilising "bricks" before being applied to the computing units. A monitoring system is used to detect and give warning of fault conditions in the computing "bricks."

The way in which "Tridac" works may be illustrated by the following examples. Suppose that the forward speed of an aircraft is represented by a voltage on a scale of 1V to 10 m.p.h. This voltage, and many others, can be shown on meters, so the speed of the aeroplane in the problem can be observed continuously by watching the meter, and recording devices are provided to give a permanent record when required. The voltage representing forward speed can be fed into an electronic integrator, which produces a second voltage which represents the distance covered by the aeroplane, again according to some prearranged scale which might be, say, 1V to 100 miles. This voltage also appears on a meter. Alternatively, the voltage representing forward speed might be fed into a "resolver," into which is also set, either by hand or automatically, the direction in which the aeroplane is flying, say, for example, 20 deg. north of east. The resolver gives out two more voltages, one representing the rate at which the aeroplane is moving eastward, and the other the rate northward. These two voltages can be fed into two integrators which give output voltages representing distances covered by the aeroplane in the easterly and



Layout of the analogue computer at the Royal Aircraft Establishment

northerly directions, and by observing these voltages on meters the position of the aeroplane can be plotted on a map. Usually, however, events move too fast for manual plotting and an automatic plotting table is provided. This is a flat board on which runs a carriage moving east and west; the carriage has a long rail, pointing north and south and carrying a pen which marks a sheet of paper laid on the board. The carriage is moved by the " eastings " voltage so that it travels towards the east by an amount representing the eastward travel of the aeroplane according to the scale of, say, 10 miles to the inch. At the same time the pen is travelling along the rail under the influence of the " northings " voltage, so that the pen traces simultaneously east and north, as the aeroplane does. If desired the paper could be replaced by a map of suitable scale. By using a more complicated resolver the variations in height of the aeroplane can be taken into account by feeding in an angle of dive or climb and another plotting table will give a continuous record of the height.

The forward speed of the aeroplane may not be constant, but " Tridac " can still perform the desired calculations no matter how the speed varies, and can indeed go further and calculate the speed from the engine thrust which it in turn calculates from the throttle settings and the engine characteristics, which can be set into the computer by setting a series of knobs. These calculations take into account the effects of changing trim of the aeroplane as fuel is used, and the changes of aerodynamic drag and engine efficiency with changing height. Besides varying its forward speed the aeroplane may also vary its direction of flight, and " Tridac " is able to calculate these variations by performing mathematical operations which represent the angles of deflection of the ailerons, rudder and elevator. These calculations take account of the change of air flow over a wing or control surface when the direction of the flight changes, and also take account of the changes of lift on the wings and other surfaces due to changes of height, speed and trim of the aeroplane. If the aeroplane is being flown by an auto-pilot the characteristics of this device can be reproduced, and if the aeroplane is using its own radar set to pick up signals from the ground or from another aeroplane the magnitudes of the signals from the radar set can be calculated, allowing for the effects of vibration, interference, &c.

In the case of a fighter aeroplane chasing a bomber the motion of the bomber can be reproduced by setting into the computer a prearranged programme, which may include periods of straight flight, slow turns, or violent evasive manœuvres. " Tridac " will then calculate what signals the radar set in the fighter will produce, allowing for the fact that both fighter and bomber are moving at high speed. All the calculations are carried out at the same speed as the actual events occur, so that if the fighter-bomber interception takes ten minutes in actual flight then " Tridac " will do the calculation in ten minutes. While the calculations are proceeding all the quantities in the problem are available as voltages, and can be observed by means of meters, plotting tables, cathode-ray tubes, &c., so that the operator can get an excellent picture of what is going on. He can stop the calculation at any time, and he can repeat as often as he wishes, using different kinds of aircraft by setting different aerodynamic characteristics, different speeds for fighter and bomber, different starting positions, &c., so the chance of an interception in any given circumstances can be found, and the most favourable tactics can be discovered. Similar calculations can be performed for guided missile systems, including beam-riding, homing and command-link systems. The use of " Tridac " for this purpose will reduce the number of actual missiles which need to be fired for test purposes, with a consequent saving of time and expense.

Since " Tridac " works in the same time scale as the real system, actual equipment, such as the motor which moves the ailerons in a powered-control aeroplane, can be included in the operation of the computer. A voltage in " Tridac " which represents the input signal to the aileron motor is brought out and fed into the actual motor which may move either a real aileron or a dummy. The aileron carries a potentiometer which provides a voltage proportional to the angle through which the aileron turns, and this voltage is passed back into the computer for the calculation of rate of roll, &c. This procedure allows measurements to be made of the effect of using different kinds of aileron motors. The pilot of the aeroplane can also be included when required. He is provided with " displays " of radar and instrument information, operated by signal voltages from " Tridac," and he operates controls of the normal kind which drive potentiometers to give another set of voltages to be fed back into " Tridac."

One of the central parts of the problems which " Tridac " has to handle is that of " axis transformation," which involves complex geometrical and trigonometrical calculations. In the fighter bomber problem the fighter-borne radar dish normally points ahead, but when the bomber comes into range the dish must be turned, say, 20 deg. to the right, and then tilted, say, 15 deg. downward. These angles are measured with reference to the frame of the fighter, and if the fighter turns or dives these angles will change, because the auto-follow action of the radar keeps the dish pointing continuously at the bomber. In many " Tridac " calculations it is necessary to know the direction in which the radar dish is pointing, in terms of an angle from true north and a depression or elevation relative to the true horizontal. To do this " Tridac " takes the angles of the dish as measured with reference to the frame of the fighter, and also takes the two angles which represent the direction in which the nose of the fighter is pointing, i.e. the bearing relative to true north and the angle of climb or dive relative to the true horizontal. This second pair of angles is available from another part of the machine which is calculating the flight path of the fighter. From the two pairs of angles " Tridac " is able to find the direction in which the dish is pointing, referred to true north and horizontal. This calculation proceeds continuously, since the position and attitude of the fighter and the position of the bomber are changing continuously.

Before any calculations can begin on " Tridac " a large amount of information has to be supplied. In the case of numbers which will not change as the problem proceeds, such as the size of an aeroplane wing, or relation between the rudder deflection and the rudder-bar deflection, there are up to 2000 potentiometers which can be set before calculation begins. For known variations, such as the change of speed of sound with height, specially shaped cams and potentiometers are provided. Adjustable electronic devices using sets of biased diodes are used for other non-linear variations.

" Tridac " has been designed jointly by the Royal Aircraft Establishment and Elliott Brothers (London), Ltd., and it has been constructed by Elliott Brothers. It will be operated by R.A.E. staff, and will be available to help industry in the same way as wind tunnels and other major items of research equipment.

B.S.R.A. Resistance Experiments on the "Lucy Ashton"*

By H. LACKENBY, M.Sc.†

No. II—(*Concluded from page 489, October 8th*)

PART III.—THE SHIP MODEL CORRELATION FOR THE SHAFT-APPENDAGE CONDITIONS

This is the third paper dealing with the resistance experiments carried out on the "Lucy Ashton" by the British Shipbuilding Research Association. It is concerned with the ship model correlation for two conditions involving different types of twin-screw shaft appendages, namely, bossings and shaft brackets. The resistance increments due to fitting these appendages have been determined and the full-scale values have been correlated with results of similar tests carried out in an experiment tank on the same series of six geometrically similar models used in the correlation of the naked hull results. The lengths of these models ranged from 9ft to 30ft. Ship-model correlation has also been made in terms of the total measured resistance. The findings have been reviewed in the light of previous work and in relation to current practices in the assessment of scale effect on appendage resistance. This appears to be the first occasion on which the parasitic resistance due to shaft appendages has been measured on a full-size ship.

THE extrapolation diagrams, Figs. 2 and 3, show the ship-model correlation in terms of total resistance for the bossing and shaft bracket conditions respectively. The Reynolds number base has been contracted and the figures are generally on the same lines as the Schoenherr extrapolation diagram used in the correlation of the naked hull conditions.

Fig. 2, which gives the results for the bossing condition, will be considered.

These naked model results align themselves very nearly parallel to the Schoenherr line; exceptions are the spots for the 9ft model at low speeds which are again 2 to 3 per cent higher than the average level of the other models on this basis. A series of cross curves (broken lines), all parallel to the Schoenherr line has been drawn for the different corresponding speeds as shown.

The faired bossing increments were then set up above the average naked hull values defined by the broken cross curves which determined the second series of cross curves shown by full lines. These represent the averaged extrapolator lines through the total resistance with bossings (circle spots) and, for reasons previously explained, the slope of these lines increases gradually with speed. These variable-slope extrapolators have been extended to the ship Reynolds number, giving a prediction for the smooth ship with bossings. The intercepts between this prediction and the measured ship resistance, which is also plotted, give the roughness allowances for sharp seams with red oxide paint on this basis. These intercepts, necessary to complete the ship-model balance, have been plotted on a base of speed in Fig. 4, where it will be noted that they compare well with the corresponding allowances deduced from the ship-model correlation of the original naked hull condition.

Incidentally, the smooth ship prediction for the naked hull, deduced from the repeat naked hull results shown in Fig. 2, agrees very closely (within 1 per cent) with that given in the previous paper.

Fig. 3 shows the corresponding total resistance extrapolation diagram for the shaft bracket conditions. With regard to this, remarks apply generally as before with the exception that the full-line extrapolators through the total resistance with shaft brackets are now themselves parallel, but of slightly steeper slope than the corresponding naked hull lines. The roughness allowances necessary to complete the ship-model balance for this condition are also shown in Fig. 4, which again compare well with those derived from the other two conditions.

The close correspondence of the roughness allowances shown in Fig. 4, which have been derived quite independently from the three different ship-model correlations, namely, naked hull, bossings, and shaft bracket conditions, bears testimony to the overall consistency and accuracy of this investigation both as regards the model and ship results.

Fig. 5 shows the ship-model correlation for the running trims. The ship values are plotted as individual observations, whereas the lines represent measurements made on the 16ft model which have been scaled up to full size *pro rata*.

With regard to the ship observations these are separated into three groups, namely, naked hull, bossings and shaft bracket conditions. Although there is appreciable scatter of the spots it is clear that stern trim increases with increasing speed. Further, there is little to choose between the spots for the naked hull and the shaft bracket conditions. Similar remarks also apply to the observations for the bossing condition except at the higher speeds, where, it will be noted, they lie noticeably lower than the others. This behaviour appears reasonable when it is borne in mind that the bossings were angled out of the flow, such that the underside of the web would become the pressure side which might well tend to reduce the running stern trim, more especially at high speed. This greater reduction in trim on the ship at high speed may be explained by scale effect on the "lift" of the bossing web and is doubtless not unconnected with the heavy scale effect in this region on the resistance increment due to the bossings referred to elsewhere in the paper.

General Remarks and Comments in the Light of Previous Work.—Previous model work has been largely directed towards the determination of the effect of different forms of shaft appendages on propulsive efficiency although resistance measurements on individual struts of relatively large scale, corresponding to shaft bracket arms, were carried out by William Froude in the Torquay tank as long ago as 1878. From these experiments, in conjunction with tests on small-scale ship models, Froude deduced that, to scale, the parasitic resistance of such appendages on the full-size ship would be about one-half that measured on the model. In the early days of the Teddington tank, Baker carried out tests on large-scale strut sections very much on the lines of those carried out by Froude and came to the same conclusion. Baker also expressed the opinion that this would hold good not only for struts, but for shaft bossings and webs as well. This doubtless is the origin of the former N.P.L. practice, abandoned only recently, in which the appendage allowance for the ship was taken to be half the increment in © measured on the model for either bossings or shaft brackets.

It is interesting to note that this practice is

Nomenclature and Symbols

C—Resistance coefficient $= \frac{R}{\frac{1}{2}\rho V^2 S}$.
e.h.p.—Effective horsepower.
F_n—Froude number $= \frac{V}{\sqrt{gL}}$.
g—Acceleration due to gravity.
L—Length of ship (LBP).
R—Resistance in general.
R_n—Reynolds number $= \frac{VL}{\nu}$.
S—Wetted surface area.
t°—Temperature of water.
V—Speed.
Δ—Displacement.
∇—Volume of displacement.
ν—Coefficient of kinematic viscosity.
ρ—Specific density.
©—R. E. Froude's resistance constant
$= \frac{125S}{\pi\nabla^{\frac{2}{3}}}C = \frac{2938R}{\Delta^{\frac{2}{3}}V^2} = 427 \cdot 1\frac{\text{e.h.p.}}{\Delta^{\frac{2}{3}}V^3}$.
where R and Δ are in tons (salt water) and V is in knots.
AP—After perpendicular.
FP—Forward perpendicular.

* Institution of Naval Architects' autumn meeting. Abstract.
† Principal assistant naval architect, the British Shipbuilding Research Association.

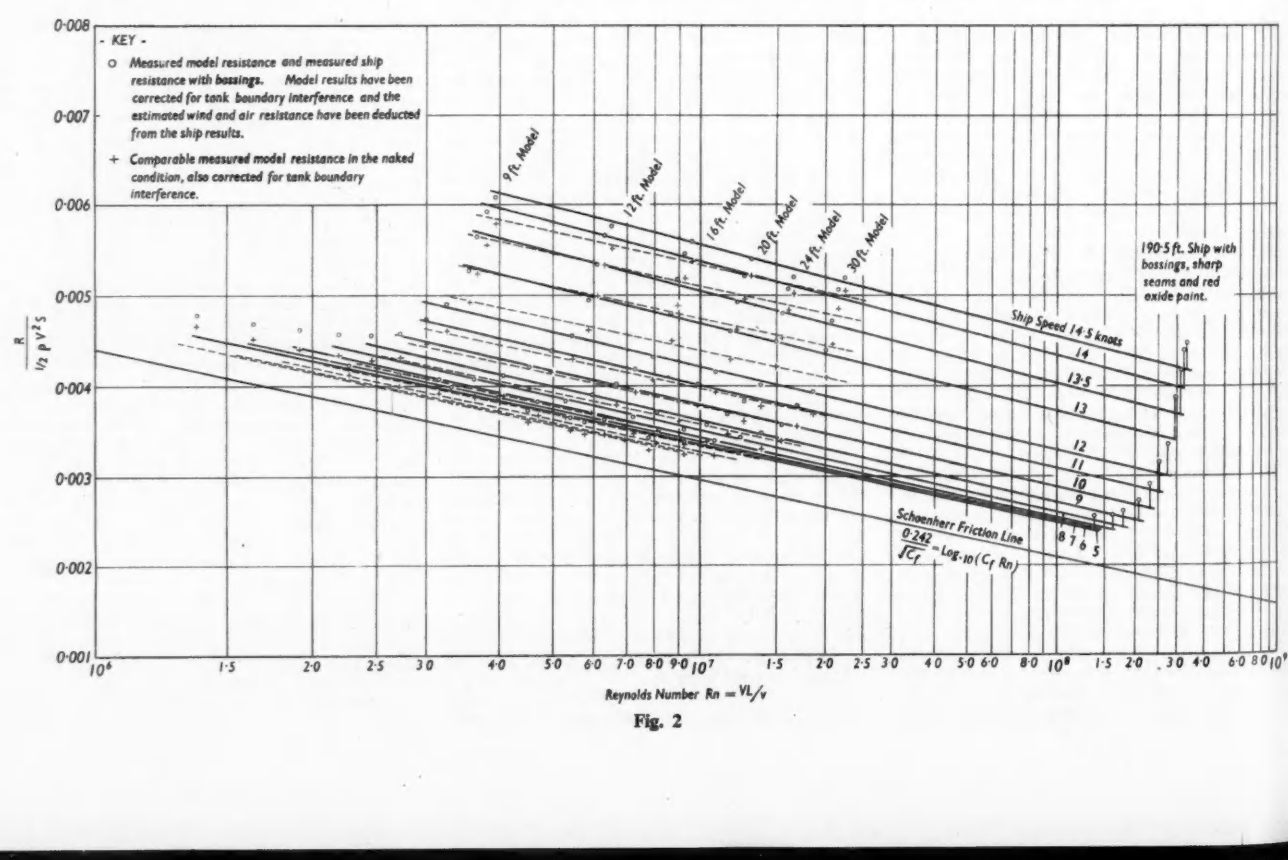

- KEY -
o Measured model resistance and measured ship resistance with bossings. Model results have been corrected for tank boundary interference and the estimated wind and air resistance have been deducted from the ship results.
+ Comparable measured model resistance in the naked condition, also corrected for tank boundary interference.
9ft. Model
12ft. Model
16ft. Model
20ft. Model
24ft. Model
30ft. Model
190·5 ft. Ship with bossings, sharp seams and red oxide paint.
Ship Speed 14·5 knots
14
13·5
13
12
11
10
9
8 7 6 5
Schoenherr Friction Line
$\frac{0.242}{\sqrt{C_f}} = \text{Log}_{10}(C_f R_n)$
$\frac{R}{\frac{1}{2}\rho V^2 S}$
0·008
0·007
0·006
0·005
0·004
0·003
0·002
0·001
10^6 1·5 2·0 2·5 3·0 4·0 5·0 6·0 7·0 8·0 9·0 10^7 1·5 2·0 2·5 3·0 4·0 5·0 6·0 8·0 10^8 1·5 2·0 3·0 4·0 6·0 8·0 10^9
Reynolds Number $R_n = VL/\nu$

Fig. 2

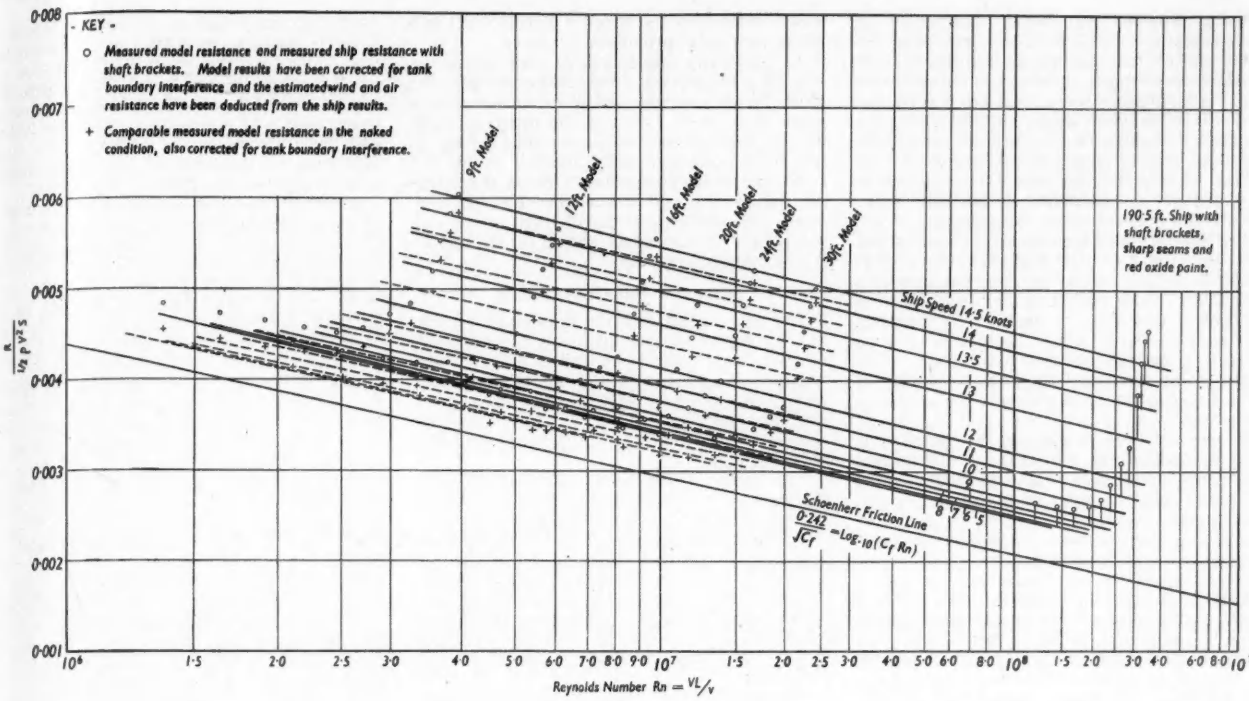

- KEY -
o Measured model resistance and measured ship resistance with shaft brackets. Model results have been corrected for tank boundary interference and the estimated wind and air resistance have been deducted from the ship results.
+ Comparable measured model resistance in the naked condition, also corrected for tank boundary interference.
9ft. Model
12½ft. Model
16ft. Model
20ft. Model
24ft. Model
30ft. Model
190·5 ft. Ship with shaft brackets, sharp seams and red oxide paint.
Ship Speed 14·5 knots
14
13·5
13
12
11
10
9
8
7
6
5
Schoenherr Friction Line
0·242/√Cf = Log·10(Cf Rn)
R/½ρV²S
Reynolds Number Rn = VL/ν

Fig. 3

roughly confirmed by the present investigations subject to reservations regarding bossing scale effect which is discussed in more detail later in this section.

It is understood that at the Admiralty tank at Haslar the practice in regard to bossings is to make the allowance on © for the ship 60 per cent of that measured on the model scale which is of much the same order as that discussed above. On the other hand, for shaft brackets, it is usual to make an independent estimate of the full-scale resistance based on Froude's large-scale tests on individual struts. Relevant formulæ for this have been published by Gawn and are as follows :—

For twin-screw open shafts and shaft bracket barrels :

Resistance of both shafts, including barrels

$$= \frac{bdV^2}{10{,}000} \text{ tons} \quad . \quad . \quad . \quad . \quad \text{(i)}$$

where

b=mean distance in feet of either shaft from the middle line plane.
d=mean diameter of shaft and shaft bracket barrel in feet.
V=ship speed in knots.

For twin-screw shaft bracket arms :

Resistance of arms, for both brackets

$$= \frac{b^2V^2}{60{,}000} \text{ tons} \quad . \quad . \quad . \quad . \quad . \quad \text{(ii)}$$

where

b=distance in feet of centre of screw from middle line plane.

This formula (ii) assumes that the total length of the arms=3b and the average thickness =0·054b. For other values the resistance is assumed to vary as total length of arms and thickness. Substituting for length and thickness this leads to the alternative formula :

$$\text{Resistance} = \frac{ltV^2}{9720} \text{ tons} \quad . \quad . \quad . \quad . \quad . \quad \text{(iii)}$$

where l and t are the total length and mean thickness of the bracket arms in feet respectively.

Applied to the full-scale "Lucy Ashton," formulæ (i) and (iii) give an allowance in terms of © of 0·041 for both shafts and brackets. This is remarkably close to the average increment in © of 0·036 actually measured on the ship.

An attempt has been made to compare the resistance increments due to the shaft brackets with data for comparable strut sections tested in both air and water. The base is a logarithmic plotting of Reynolds number referred to the actual bracket arm or strut section, i.e. Vc/ν where the length characteristic c is the length or chord of the cross section in the plane of motion. The ordinates are plotted on an ordinary linear scale of resistance or drag coefficient defined as $R/(\frac{1}{2}\rho V^2 cl)$, where l is the length of the bracket arm or strut. The area used in the resistance coefficient is therefore cl, the projected area of the strut (one side) in the plane of motion, as is usual in the presentation of strut data.

For the resistance increments due to the shaft bracket appendages the speed has been taken as the forward speed of the ship without correction for wake, although in a ship of the proportions and fineness of the "Lucy Ashton" it is not considered that the wake in way of the bracket arms would be very strong. Another aspect which tends to upset the quantitative comparison with the strut data is the fact that the bracket arms were set fore and aft and not aligned in the stream flow. This misalignment would probably be small and the consequent increase in drag would not be expected to be appreciable.

The resistance increments measured on the models align themselves quite well on this basis and the general trend in the reduction of the resistance coefficient with increasing absolute size appears compatible with the increments measured on the ship. The undulations in individual increment curves bear a certain resemblance to each other and may be genuine to some extent, but they are generally within 1 per cent of the total measured resistance, which is considered to be the order of accuracy of measurement, and it would perhaps be unwise to attach too much importance to them.

The shaft bracket arms were of symmetrical lenticular section 12in chord and 4in maximum thickness. Unfortunately, data for strictly comparable struts do not appear to be available, but results are shown for a number of struts of the same (or nearly the same) fineness ratio (3 to 1) which were of the usual streamlined section, being fuller towards the leading than the trailing edge. Whereas this difference in section shape may not affect the drag to any great extent, when coupled with other differences referred to above, the comparison of the strut data with the resistance increments measured on the models and the ship must be regarded as qualitative rather than quantitative. The data shown includes tests in water by Baker and W. Froude, and tests in air by Jones and Levy and Frazer and Simmons.

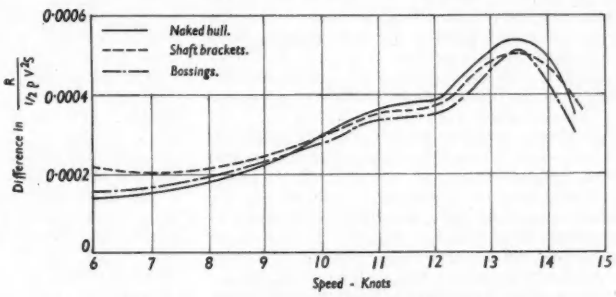


Fig. 4—Differences between smooth-ship predictions from models and full-scale resistance

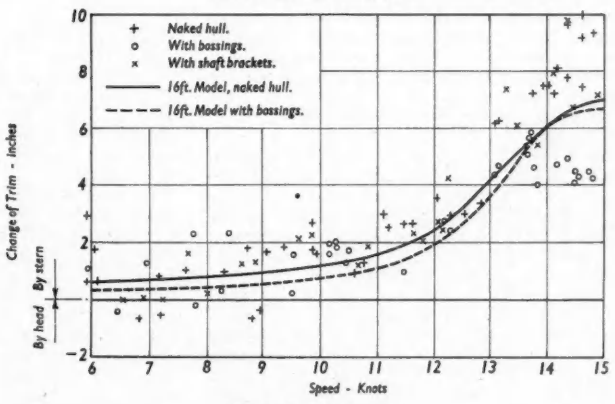


Fig. 5—Running trims

Coming now to an overall comparison of the information given, the strut data lie appreciably higher than the calculated skin friction resistance for a plane surface, and the difference is to be ascribed to form effect on skin friction and also probably to separation effects. Again, although the comparison of the model increments and strut data is largely qualitative the former lie the higher, and this would be expected as they include the resistance of the bare shafts for which no deduction has been made.

The increments measured on the ship compare well with the estimates made by the Froude formulæ quoted earlier for the brackets plus bare shafts, and according to these formulæ the contribution made by the brackets compares well with the strut data. There is also good agreement among the strut data itself. The single value available for the resistance of Froude's strut compares well with the later data for struts.

To sum up, it can be said that the overall scale effect behaviour shown by the shaft bracket increments is in keeping with data for individual struts and that the order of magnitude is also comparable.

It has not been possible to make similar comparisons for the increments due to bossings owing to lack of comparable data.

Apart from the individual strut tests referred to above, the most comprehensive investigation on appendage scale effect hitherto was that undertaken by Allan, at the N.P.L., on a series of three geometrically similar models of a twin-screw form. The model lengths were 18·7ft, 22·96ft and 33·67ft, and the resistance increments due to fitting both bossings and shaft brackets were determined. The findings over this range of models were briefly as follows :—

Appreciable scale effect was evident on the shaft bracket increments and the general behaviour was very similar to that found in the present investigations, in that the cross curves at constant Froude number were roughly parallel.

For the bossings, however, Allan found no perceptible scale effect on the resistance increment over the range of models tested, in that the cross curves of constant Froude number were horizontal at all speeds. He also developed arguments to suggest that in translating the results to the full-size ship the scale effect would be slight, if any.

This behaviour, in the case of the bossings, differs sharply from that observed in the present investigation where there was scale effect varying gradually over the speed range from zero at the lowest speeds to quite an appreciable effect at intermediate and higher speeds. There was an important difference between the two bossings which may explain the different behaviour. In Dr. Allan's tests the bossing webs were arranged in the natural undisturbed flow around the form, whereas in the present investigations the webs were inclined 20 deg. below the optimum angle. In the former it may be argued that there was comparatively little separation flow, in which event the resistance increment would be largely made up of skin friction and form resistance. In the circumstances, this parasitic drag might not be expected to show a heavy scale effect, at least over the restricted range of model lengths of 18·7ft to 33·67ft. In this connection, it is pertinent to observe that over the corresponding range of model lengths in the present tests, say, 16ft to 30ft, the decrement is generally quite small ; it is nevertheless quite noticeable at the highest speeds.

With regard to the form of bossing used where the webs were aligned across the undisturbed stream flow, separation effects probably played a predominant part in the resistance behaviour. As far as bossings are concerned it would therefore appear that in assessing scale effect it is important to distinguish between the two types—that is, whether the webs are arranged parallel to or across the flow.

With regard to the relative merits of the bossings and shaft brackets, there is little to choose between the two as far as the actual ship is concerned. Over the working speed range the shaft brackets appear to offer slightly less resistance, but the difference is generally less than 2 per cent. However, this comparison applies strictly to this ship and to the particular arrangement of appendages. These remarks apply only to the towed resistances (or effective horsepower) and not to the overall propulsive efficiency.

As previously mentioned, at high speeds the bossing effect is very much exaggerated on the model scale and this leads to the important result that above 13 knots the order of merit of the bossings and shaft brackets shown by the model tests is actually reversed on the full scale, the bossing increments being the larger on the models and the smaller on the ship. Below this speed the order of merit of the two forms of shaft appendage shown on the models is maintained on the ship.

Summary and Conclusions

The paper deals with the ship-model correlation for two conditions involving different types of twin-screw shaft appendages. These were "dummy" appendages and on the ship they were built up with welded sheet steel. The ship trials were carried out with the hull in the normal service condition, i.e. sharp seams with red oxide paint.

This appears to be the first occasion on which the parasitic resistance due to such appendages has been measured on a full-size ship.

The resistance increments due to fitting these appendages have been determined and the full-scale values have been correlated with the results of similar tests carried out in an experiment tank on the same series of six geometrically similar models used in the correlation of the naked hull results. The length of these models ranged from 9ft to 30ft.

The investigation has shown pronounced scale effect on the resistance increments due to fitting bossings and shaft brackets and for both types of appendage the trends apparent on the model scale have been generally confirmed by the full-scale ship results. The details are briefly as follow :—

Bossings.—The scale effect varied gradually over the speed range from zero at the lowest speeds to quite an appreciable effect at intermediate and higher speeds. Over the working speed range for the ship, say, 8 to 12 knots and for the usual model lengths of 12ft to 20ft, the ship increments, to scale, were roughly one-half those measured on the models. At the higher speeds the model increments were much more exaggerated and more especially on the smaller models. It is considered that this variable scale effect is due in some manner to interaction between the parasitic drag of the appendages and the wave-making resistance of the hull.

The above behaviour differs from some previous work confined to the model scale, which showed no perceptible scale effect with increasing size at all speeds. It is considered that the difference may be due to the fact that in that instance the bossing webs were aligned in the undisturbed stream flow, whereas in the present investigation the webs were inclined across it. In assessing scale effect, therefore, it would appear important to distinguish between the two types of bossing.

Shaft Brackets.—In this instance the scale effect did not show any tendency to vary with speed and over the working speed range and usual model lengths, the ship increments, to scale, were roughly one-half of those measured on the models.

The overall scale effect behaviour shown by the resistance increments due to the shaft brackets is in keeping with previous work on the model scale and also with data for comparable individual strut sections tested in both air and water. The magnitude of the resistance increments also appears to be of the same order as the strut data ; in particular, the ship increments showed very good agreement with independent estimates made from formula used at the Admiralty Tank, Haslar, which were based on large-scale tests in an experiment tank on individual struts and shafts.

Subject to the reservation on bossing scale effect referred to above, current practices in the assessment of appendage resistance and scale effect have been generally confirmed.

With regard to the relative merits of the bossings and shaft brackets as fitted to the ship between 8 and 13 knots, the latter offer slightly less resistance and elsewhere the position is reversed. The differences are quite small, however, and generally less than 2 per cent. At the service speed in the neighbourhood of 12 knots, the increments are 5 per cent and 3½ per cent of the total resistance for the bossings and shaft brackets respectively. This comparison applies strictly to this ship and to the particular arrangements of appendages. Had the bossing webs been aligned to the stream flow the slight advantage in resistance of the shaft brackets might well have been offset.

As mentioned above, at high speeds the bossing effect is very much exaggerated on the model scale, and this leads to the interesting and important result that, above 13 knots, the order of merit of bossings and shaft brackets shown by the model tests is actually reversed on the full scale, the bossing increments being the larger on the models and the smaller on the ship. At lower speeds the order of merit of the two forms of shaft appendage is the same on the models and the ship. It is considered that this curious behaviour may be due to scale effect on interaction between the flow over the bossings and the very acute wave making above 13 knots, as referred to earlier. This region corresponds to the well-known "hump" in resistance curves which generally occurs at about $V/\sqrt{L}=1{\cdot}0$, where there is adverse interference between the bow and stern wave systems.

Ship-model correlation has also been made in terms of total resistance on the Schoenherr basis on similar lines to that used in the previous paper for the naked hull conditions. The derived roughness allowances for the hull surface in both the bossing and shaft bracket conditions show a large measure of agreement not only in themselves, but also with those for the original naked hull condition. (These roughness allowances all refer to the clean hull surface with sharp seams and red oxide paint.) It is considered that the close correspondence of these three independent ship-model correlations bears testimony to the overall consistency and accuracy of the investigations, both as regards model and ship results.

Technical Reports

American Standard Building Code Requirements for Masonry. Miscellaneous Publication 211. National Bureau of Standards' Office of Scientific Publications, Washington 25, D.C., U.S.A. Price 20 cents.—This publication of the American Bureau of Standards is a revision of an earlier edition (No. 174) published in 1944. It gives a complete code of minimum requirements for masonry construction in the United States, for all kinds of masonry work except reinforced masonry and thin veneers.

Selenium, A Short Review of its Production and Utilisation with reference to the Current Shortage. D.S.I.R. H.M. Stationery Office. Price 1s. 6d.—This recently published survey deals with the serious shortage of selenium which has arisen in recent years, due to the expanding demands mainly from the electrical industry but also from the glass industry. Although of wide occurrence, selenium is only found in small concentrations, usually in association with sulphide ores, and for that reason it seems likely that it will remain a by-product of other processes, of which the chief one is the electrolytic refining of blister copper. While raw copper may contain something like 0·01 to 0·1 per cent of selenium, the anode slime formed in the refining contains up to 12 per cent. The U.S.A., Canada and Sweden are the chief producers, but the U.S.A. are net importers. The report considers that the biggest increase in output could be obtained by improving the recovery yield which at present is only about 30 per cent. A minor but nevertheless important contribution to the needs of this country could be made by recovery from pyrites which is used in sulphuric acid manufacture ; this is a question which the Chemical Research Laboratory of D.S.I.R. is investigating. The main application of selenium is to metal rectifiers, which in respect to load capacity and reliability are superior to the cuprous oxide type. The report states that no commercially acceptable equivalents are at present available for the selenium power rectifier, although germanium, silicon and titanium dioxide, as well as some other substances, have interesting long-term prospects. There is also the theoretical possibility of substantial savings in the amount of selenium employed per cell, but our scanty knowledge of the actual conditions and the difficulties of manufacture make for slowness in development. Other uses of selenium are in the glass industry, either as a ruby stain or as a decoloriser, to mask the green due to iron impurities. Here again, while economies are possible, no satisfactory alternatives are known. The use of selenium in pigments is also often unavoidable where resistance to heat is required.

Work of the U.S. Atomic Energy Commission

(By Our American Editor)

THE sixteenth bi-annual report to Congress of the U.S. Atomic Energy Commission (A.E.C.) indicates that the production of uranium ore and uranium concentrates in the United States attained record levels during the first half of this year. The interest in prospecting for uranium increased significantly, being stimulated by several recent discoveries of large uranium ore bodies. Many large and long-established mining companies have now shown greater interest in this strategic material and entered the uranium mining industry. With the advent of more large mines, uranium mining is becoming more stable and modern, and large-tonnage mining methods are coming into wider use. By May 1, 1954, some 430 mining operators were producing and delivering uranium ore from 530 mines in the United States, with the Colorado Plateau remaining the most important source of domestic uranium production. Nearly all of the large ore bodies discovered in the past two years are in this area. At one time there were only four known uranium deposits containing ore reserves in excess of 100,000 tons of ore. Now at least fifteen such large ore bodies are known and several of them greatly exceed 100,000 tons.

Uranium minerals are now known in at least eighteen different stratigraphic horizons on the Colorado Plateau. Important uranium production is being derived from five of these formations. The Salt Wash member of the Morrison formation, occurring throughout the Plateau and at one time being the only producing horizon, continues to be an important producer. Intensive exploration in recent months expanded the producing areas of this formation. Other important producing formations include the Shinarump, Chinle and Moenkopi in the Monument Valley, the White Canyon, Green River Desert, Big Indian Wash, and San Rafael Swell areas of Arizona and Utah, and the Todilto limestone of the Zuni and Lucero Uplift between Albuquerque and Gallup, New Mexico. Vanadium producing ores of the Entrado formation near Rifle, Placerville, and Rico, Colorado, have also produced by-product uranium. The Lehigh Coal and Navigation Company in Eastern Pennsylvania recently announced plans for the production of uranium from a small ore body the company has developed near Mauch Chunk. This will be the first uranium production in the eastern part of the United States.

The discovery and development of several large ore bodies has created a need for additional ore processing facilities on the Colorado Plateau. Ore reserves are now at a very high level and ore production is expected to exceed the present level of output during the next few years. Ground was broken in January by the Kerr-McGee Oil Industries, Incorporated, for a new ore-processing mill at Shiprock, New Mexico, to treat ores produced in the Lukachukai and Carrizo Mountain areas. The completion of this mill, which is expected late this year, will bring to nine the number of mills currently in operation on the Colorado Plateau. In April and May of this year, the third and fourth plants for the by-product recovery of uranium from Florida phosphate rock were completed by the International Minerals and Chemical Corporation at Bartow, Florida, and by the Virginia-Carolina Chemical Corporation at Nichols, Florida. These plants will begin continuous production shortly. The Commission is negotiating with several other phosphate chemical firms for the construction of additional facilities for this purpose.

Production

A sharp rise in the production of fissionable materials occurred during the first six months of 1954, and the unit cost of production of fissionable materials was lower than in the preceding six months. The Savannah River construction project in South Carolina neared completion and a number of its components were placed in operation. At Hanford, Washington, the construction of additional reactor capacity also proceeded on schedule. The first gaseous diffusion plant at Paducah, Kentucky, went into full operation, as did portions of the second Paducah plant. The addition to the Oak Ridge gaseous diffusion plant is now partially completed.

An interesting characteristic of the present American atomic energy industrial complex is the degree of flexibility that has been built into the system. Operational flexibility is available through the re-use of the same source material. Given the proper processing facilities, natural uranium can be placed in a reactor to produce plutonium and then the depleted uranium can be enriched in gaseous diffusion plants by an amount sufficient to permit re-use in the reactor. This flexibility of operation makes it possible to operate the various production facilities to achieve maximum economic use of uranium feed. Any sudden changes in needs for specific items of output from the system can be met by adjusting the level of operation of various plants and diverting material among processes and plants. The ability of nuclear reactors to produce materials other than plutonium provides further flexibility in the production of atomic materials. The units at both Hanford and Savannah River have this potential.

In the course of developing processes for the production of fissionable materials, all components of the gaseous diffusion process, such as barriers, gas compressors, gas coolers and coolants, have been under study since the K–25 plant at Oak Ridge was put into operation in 1945. As a result of these studies, improvements have been made in every part of this process. The net results of these improvements, which have been made over the years, are that the capital costs for diffusion plants built since 1946 have been many million dollars less than they would have been if the plants had been built using the equipment which was used in the original K–25 plant. In addition to the savings in capital investment, these improvements also have resulted in annual operating costs which are several hundred million dollars less than they would have been if plants of the K–25 design had been built.

The total gaseous diffusion plant capacity, including that under construction, has now reached the point where even small improvements in process efficiency have a substantial value in terms of increased production. The field for further improvements has by no means been exhausted. A number of new developments, which were made too late to be included in plants built during the current expansion programme, can be incorporated in existing plants when the most efficient way to make these changes has been established. These changes are expected to result in further large savings.

Similar progress has been made in the field of plutonium production. For example, the capacity of the original production facilities at Hanford has been increased substantially. New facilities, which have been built or are under construction, are capable of even more economical production. Continuing success of process improvements to increase power levels is an optimistic indication that the ultimate capacity of these units has yet to be reached. In the intricate chemical process of extracting plutonium from the highly radioactive uranium discharged from the piles, important advances were made also. The new chemical plants separate both plutonium and uranium from fission products. The uranium thus reclaimed can be used as feed for the gaseous diffusion plant. This new chemical process has proven far more economical than the process originally used.

The feed materials phase of the present production programme deals with the conversion of uranium ore and concentrates to uranium metal suitable for reactor fuel, or to uranium hexafluoride to be fed to the gaseous diffusion plants. While these operations present some special problems, they are much more similar to conventional processes of the chemical and metals industries than are reactor and diffusion plant operations. Feed materials process development has undergone substantial expansion to serve the increased reactor and diffusion plant capacity. Many improvements and new processes of great potential importance are now being studied, and some of these developments have already been incorporated into production practice.

Military Application

The weapons research and development programme of the A.E.C. was advanced by the tests conducted at the Pacific proving ground during the period of the present report. This test series, known as "Operation Castle," was conducted by Joint Task Force 7 composed of personnel of the Commission and the U.S. Army, Navy and Air Force. Following the pattern established for earlier tests at the Pacific proving ground, the Commission, through the Los Alamos Scientific Laboratory and the weapons research laboratory of the University of California Radiation Laboratory was responsible for the test devices. Both the A.E.C. and the Department of Defence participated in the scientific measurements. The Department of Defence was responsible for certain supporting operations and services. These tests were successful with regard to the development of thermo-nuclear weapons. Special mention for their part in this enterprise was made of the management and staff members of the Los Alamos Scientific Laboratory as the agency primarily responsible for these thermo-nuclear developments.

One of the oldest buildings occupied by the Los Alamos Scientific Laboratory was demolished during the spring of 1954. The temporary wood frame structure, known as "D" building, was erected in 1943 when the first scientists on the Laboratory's staff were moving into Los Alamos. The early extensive chemical and metallurgical work on the characteristics of plutonium and the development of safe methods of processing this dangerous material were conducted in the structure. The first pieces of plutonium readily visible to the naked eye were produced in the building, and later, the nuclear parts of the bombs set off at Trinity Site, near Alamogordo, New Mexico, and at Hiroshima and Nagasaki were produced there. No harmful radiation was received by any person working in the building during its long occupancy. However, some room surfaces were contaminated with small quantities of radioactive materials. The experience gained in the use of "D" building has been of value in the design of a permanent structure which was recently build as its replacement.

Reactor Development

Progress in the Commission's programme of developing improved reactors for industrial nuclear power and for naval and aircraft propulsion and other military requirements continued during the first six months of 1954. A report describing the Commission's programme of industrial nuclear power development over the next five years was sent by the A.E.C. to the Joint Congressional Committee on Atomic Energy on February 5th. The report presented a specific pattern of research and development to be followed in a major effort to decrease the cost of nuclear power. It allows an increased participation by contractors who are now engaged in the reactor development programme and encourages additional groups outside the Commission to participate. The programme provides for development of five distinct technological approaches with experimental reactor power plants and outlines general research and development activities to be undertaken over a five-year period. These projects, their total estimated cost over the entire five years, and the dates estimated for the completion of experimental plants are shown in Table I. None of these plants is expected to produce economically competitive electrical power because of their small size, experimental nature, or

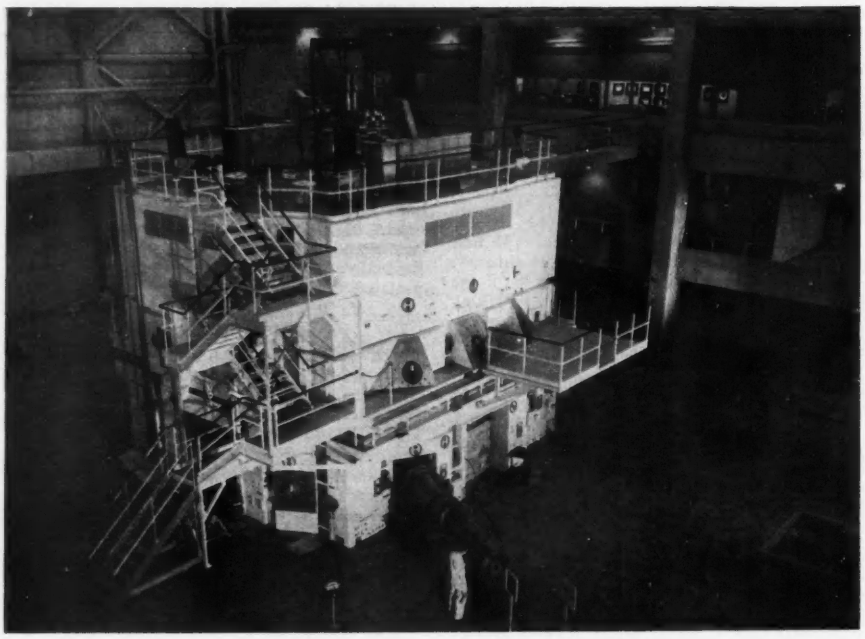


Fig. 1—The Materials Testing Reactor of the Atomic Energy Commission

Fig. 2—Radiation level check at horizontal beam hole of Materials Testing Reactor

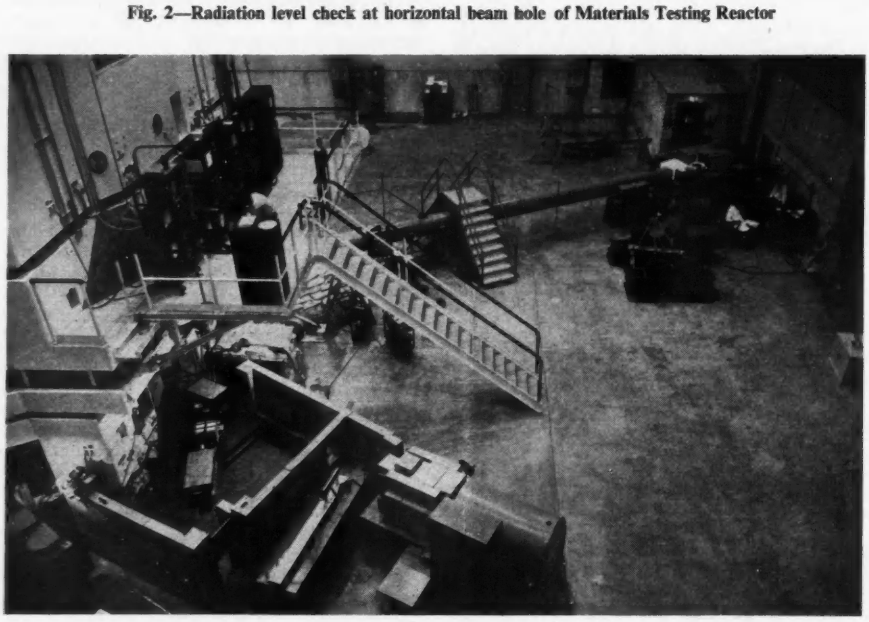


Fig. 3—Floor of Materials Testing Reactor with crystal neutron spectrometer in foreground and neutron "Chopper" tunnel in background

limitations of the new technology. However, in the opinion of the A.E.C., there is reasonable expectation that electricity will be generated from nuclear fuel at a cost competitive with electricity generated from fossil fuels in the foreseeable future.

The Westinghouse Electric Corporation continued its development work on the Pressurised Water Reactor (P.W.R.), which is to be the first

TABLE I

Project (research) development and construction	Estimated cost, million dollars	Estimated completion	Experimental scale
1. Pressurised Water Reactor	85	1957	Full
2. Boiling Water Reactor	17	1956	Medium
3. Sodium Graphite Reactor	10	1955	Medium
4. Homogeneous Reactor	47	1956–58	Medium
5. Fast breeder reactor ...	40	1958	Medium
Total	199	Five years	

civilian nuclear power plant in the United States. This reactor is moderated and cooled by water and uses slightly enriched uranium fuel. The P.W.R. plant is to have a power of approximately 300MW of heat, and an output of at least 60MW of useful electricity. The project is not expected to produce electricity at costs competitive with those of plants using conventional fuels. However, it will make possible firm cost estimates for the future and provide design and technological experience obtainable only from a full-scale plant operation. An article describing the present status of the scheme was published in THE ENGINEER for October 1, 1954.

It was formerly believed that boiling within the core of a water-cooled reactor would cause unstable operation. However, experiments conducted last year by the Argonne National Laboratory at the National Reactor Testing Station in Idaho have indicated this to be untrue. In addition, these experiments may have an important bearing on the safety of industrial power reactors, for it is now possible that boiling reactors may be designed to operate in a stable self-regulating manner, shutting themselves down without serious damage in case of trouble. The tests at the National Reactor Testing Station consisted of setting up and operating a water-cooled and moderated reactor and imposing conditions which would normally be expected to cause a "run away." It was previously assumed that under these circumstances the core would melt and allow the escape of fission products. However, these things did not happen, and the experimental results with a small, temporary water-cooled and moderated reactor showed that power excursions could take place quite rapidly and neither produce melting of the fuel nor radioactive contamination of the surroundings. In experiments which allowed the power to rise to several thousand kilowatts in a fraction of a second, the steam cut off the nuclear reaction completely before a dangerous temperature was induced. It is believed that this mechanism when applied to power reactors could be a safety device making it impossible for the nuclear reaction to create dangerously high temperatures. Furthermore, a reactor used as a direct source of steam in a power plant might reduce capital costs by eliminating the heat exchanger outside the reactor, by reducing the pressure of the primary coolant system, and hence the pumping power required for the system. Current plans call for starting construction, during the year ahead, of an experimental boiling water reactor designed to produce 20MW of heat and 5MW of electricity to be completed in the winter of 1956. The reactor will make use of normal uranium fuel as well as enriched uranium 235 and will be moderated and cooled by ordinary water. As in the case of the PWR, the slight enrichment of fuel is necessary to bring a light water moderated reactor to criticality. An important aspect of tests with the experimental boiling water reactor will be to determine whether it can be operated without troublesome or hazardous deposit of radioactivity in the turbine, condenser, feed water pumps, or other equipment outside the reactor. The deposited radioactivity might cause major maintenance problems in the event of failure of the equipment.

Although a proposed sodium-cooled, graphite-

moderated reactor has been determined to be feasible in principle, there are still numerous aspects of such a plant that have not been tested in actual practice. For example, these include the upper limits for fuel and coolant temperatures, burn-up, and other operating variables. North American Aviation, Incorporated, the major contractor exploring the sodium-graphite approach, continued its investigation in this field. The firm has agreed to contribute 2·5 million dollars of the 10,000,000 dollars required for the development, construction and operation of a graphite-moderated sodium reactor experiment (S.R.E.) during the period 1954–58. The S.R.E. is planned to produce 20MW of heat and would not be equipped with a turbo-generator.

A full-scale reactor, using slightly enriched uranium fuel, would be expected to have a regeneration ratio of 0·9. If charged with uranium 233 and thorium, it is believed that it would have a ratio slightly greater than one and operate as a power breeder producing more uranium 233 than it burns. Tests with the sodium reactor experiment are planned to include fuel element performance, maximum permissible fuel element and structure temperatures and corrosion and radioactive transfer. The reactor temperature and specific power will be increased gradually to determine performance limitations. The completion of construction and the beginning of experimental operation of this reactor are scheduled for 1956.

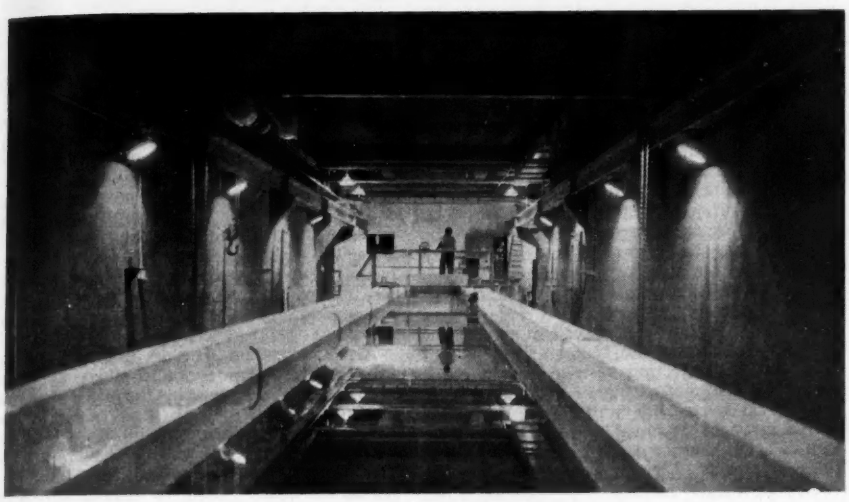


Fig. 4—Spent fuel storage canal underlying the Materials Testing Reactor of the Atomic Energy Commission

The Oak Ridge National Laboratory continued the operation of the homogeneous reactor experiment (H.R.E.) No. 1 during the early months of 1954. This first power reactor of its type circulated uranyl sulphate fuel solution at nearly 500 deg. Fah. under a pressure of 1000 lb per square inch and at a power density of 30kW per litre. It had a heat output of 1000kW and fed a small turbo-generator. In testing the self-regulation of H.R.E. No. 1, the reactor power was purposely increased as rapidly as possible, but the reactor did not "run away." Its power rose quickly to an abnormally high, but very short, peak and then levelled off at a moderately high value as the expanding fuel solution caused the core to lose reactivity. The reactor also demonstrated safe operation after its fuel solution became highly radioactive from fission products, and while a mixture of hydrogen and oxygen was formed by the irradiation-produced décomposition of the solution water. The H.R.E. No. 1 was dismantled in the spring of 1954 to make way for the construction—in the same building at Oak Ridge—of the homogeneous reactor experiment No. 2, which should be completed and put into operation early in 1956.

The H.R.E. No. 2 will have a heat output of 5000kW. Its primary purpose is to produce a simplified, mechanically reliable plant demonstrating operability and reliability over a long period under conditions more closely simulating those of a full-scale reactor. It will furnish steam for a small turbo-generator and will dissipate the excess steam. The plant will include chemical processing equipment for the purification of the fuel solution by removing fission products. It will also seek additional information on the effects of irradiation on the corrosion of materials and on the chemical stability of the fuel solution.

In the development of the homogeneous reactor, corrosion tests without irradiation demonstrated the compatibility of a dilute uranyl sulphate solution with a number of materials at high temperatures. Data on the effects of varying temperatures, salt concentration, acidity and solution velocity were also obtained. The Oak Ridge National Laboratory completed a full-scale model of an "in-pile loop," which consists of an assembly of piping, pumps and instruments for the purpose of circulating a fuel solution past samples of different materials while they are under intense neutron bombardment in the Low Intensity Test Reactor and the Materials Testing Reactor. Information obtained from these and other investigations will be applied to the design of a Homogeneous Thorium Reactor (H.T.R.), which is now in the planning stage. The H.T.R. is to produce about 65MW of heat, of which some 16MW will be converted into electricity. It will have a blanket of thorium from which uranium 233 will be produced.

Although the core diameter of the Homogeneous Thorium Reactor will not be as large as that of a full-scale plant, the thickness of the thorium blanket and the concentration of fertile material will be the same as those used for a central power station application. In addition, two chemical plants—one for removing fission products from the fuel solution and another for separating the uranium 233 from the thorium blanket—are to be an integral part of the reactor. Following the development and design of the H.T.R. by the Oak Ridge National Laboratory, construction is expected to begin during 1957 and be completed in 1959. The reactor will probably start operating with uranium 235 and change later to uranium 233, as this synthetic fissionable material is produced in the blanket.

After two years of operating experience with the Experimental Breeder Reactor (E.B.R.) No. 1 at the National Reactor Testing Station in Idaho, the A.E.C. plans to build a much larger unit, the Experimental Breeder Reactor No. 2. The E.B.R. No. 1, developed and operated by the Argonne National Laboratory, was the first reactor to produce electricity and to demonstrate breeding. The E.B.R. No. 2 is planned to produce 62·5MW of heat power and 15MW of electrical generating energy. The E.B.R. No. 1 supplied 1400kW of heat and 170kW of electricity. The E.B.R. No. 2 will closely resemble a large central power station breeder reactor in power, control, fuel handling and other aspects. In addition to providing information on engineering matters, the E.B.R. No. 2 will be operated to develop fuel-handling techniques, power-cycle conditions, core and blanket concentration, and component designs.

Plutonium will be used as fuel in the E.B.R. No. 2 although it may be necessary to supplement it with uranium 235 for metallurgical reasons. However, the fuel charge will be changed to plutonium later. The blanket will be composed of natural or depleted uranium 238 which will be transmuted into plutonium. A greater production of plutonium will be achieved by using this element as a fuel than by using uranium 235. The objective will not be to produce a large quantity of fissionable material, but rather to test engineering aspects of the reactor and its auxiliaries.

Early in January, the Department of Defence requested that the A.E.C. co-operate with the U.S. Army Corps of Engineers in a programme to meet military requirements for nuclear power plants. Studies by the Army and the Commission had previously established that nuclear power plants for installation at remote military bases appear to be technically feasible and would have strong military advantages. The Commission and the Army have agreed to initiate the programme by building a prototype of a small nuclear power plant. The prototype will be based on the design of a pressurised light water reactor by the Oak Ridge National Laboratory. This nuclear plant, in order to approach a competitive status with conventional military plants in certain situations, will be designed to make use of proven components requiring the minimum of development.

Experimental operation of the prototype Submarine Thermal Reactor, Mark I, in a land-based submarine hull at the National Reactor Testing Station in Idaho was continued by the Westinghouse Electric Corporation as a part of the programme for testing this reactor. Power for the U.S.S. "Nautilus," which was launched at Groton, Connecticut, on January 21st, will be furnished by the Submarine Thermal Reactor, Mark II.

The construction of the second nuclear-powered submarine, the U.S.S. "Sea Wolf," continued at the Electric Boat Division of the General Dynamics Corporation, Groton, Connecticut. The ship will be powered by the Submarine Intermediate Reactor, Mark B. The prototype power plant for this vessel, which is known as the Submarine Intermediate Reactor Mark A, neared completion at West Milton, New York, as the Electric Boat Division progressed with the installation of machinery in the hull section. The hull section was moved into the spherical power plant building on March 20th. Research and development on both the Mark A and Mark B plants continued at the Knolls Atomic Power Laboratory, near Schenectady, which is operated for the A.E.C. by The General Electric Company.

The accompanying illustrations, Figs. 1 to 4, give a general idea of one of the Atomic Energy Commission's reactor installations, namely the Materials Testing Reactor, which, as mentioned above, is one of the facilities of the Oak Ridge National Laboratory.

Physical Research

Research with high energy beams from the cosmotron at the Brookhaven National Laboratory continued during the first six months of 1954 and it was directed chiefly toward gaining a better understanding of the structure and behaviour of protons and neutrons. One of the well-known characteristics of protons and neutrons is that they emit short-lived particles called mesons upon colliding with other nucleons of high energy. Quantitative information about meson creation has now been obtained under known and controllable conditions through the use of high-energy accelerators. Indicative of the strength of the nuclear forces with which one nucleon acts upon another is the answer to the question of whether "pi-mesons" (whose mass is equal to 280 times the mass of the electron) are always created singly or whether they can also be created in pairs. Experiments showed

that not only can pi-mesons be created in pairs, but that at an energy level of 200 MeV pair meson production actually predominates. Experiments with both cloud chambers and electron counters showed that neutron-proton collisions usually resulted in one positive and one negative meson, and proton-proton collisions in two positive mesons. Although there was ample energy available, no cases of three or more mesons being created simultaneously were observed.

The creation of mesons heavier than protons or neutrons—"hyperons"—was also studied. The hyperon is unstable and may be thought of as a combination of a nucleon and a pi-meson. The system lives only for a fraction of a second and then decays into a proton or a neutron and a pi-meson. Whether these hyperons can be created singly is of considerable significance. Cloud chamber photographs showed many examples of a hyperon being produced together with another heavy particle, but no example of one being produced singly. Evidence also indicated that protons of at least 1500 MeV energy are necessary to produce hyperons. This high energy again suggested that another heavy particle must accompany their creation.

At the California Institute of Technology, investigators continued to use the 500 MeV electron synchrotron to perform fundamental experiments on the interaction of nuclei and elementary nuclear particles. Particular emphasis was placed on the photo-disintegration of the deuteron and the photo-production of charged mesons from deuterium. The photo-disintegration of the deuteron by high energy photons has been studied by measuring the emitted protons with a counter telescope. Results have been obtained for protons emitted at different angles and different energies. As the photon energy is increased from 80 MeV, the cross section decreases and then shows a plateau or even a slight increase near 300 MeV, followed by a rapid decrease in the differential cross section for higher energy. In the production of mesons from deuterium by energetic photons, it was found that the values obtained for the ratio of negative to positive mesons produced at forward angles lie between 1·0 and 1·2 and is almost independent of energy. In the backward direction, however, at 140 deg. the ratio is 1·4 between 200 MeV and 300 MeV and increases somewhat at greater photon energies.

The Los Alamos Scientific Laboratory made further progress in determining whether the free neutrino exists in nature. If it exists, the neutrino is expected to be capable of causing the transmutation of free protons into free neutrons, accompanied by the creation of a positive electron (positron). The probability of this occurring when one neutrino passes a given proton is exceedingly small. However, if enough protons are placed in an intense beam of neutrinos, such as is supposedly emitted by a large nuclear chain reactor, the transmutation should occur often enough to be detected with appropriate apparatus. First attempts to detect this event were made in 1953 near a large pile at Hanford, Washington, when apparatus designed at Los Alamos was used to record the frequency of observation of two almost simultaneous occurences—one of which was the capture of a neutron and the other may have been the presence of a positron. The predicted pair of events was observed substantiating the theory. The next step in proving that these events are caused by neutrinos will consist in demonstrating that one of the pair is in fact a neutron "born" in the apparatus, and that the other is actually a positron produced at the same instant. An improved detector was designed at Los Alamos using liquid scintillation techniques, and is now in the process of assembly. Consideration is being given to setting up this detector near a large reactor at the Savannah River plant of the A.E.C. in a further attempt to identify definitely the transmutation of protons to neutrons by neutrinos.

Additional data on the interaction of neutrons with nuclei were obtained using the neutron beams from the Brookhaven reactor. Total neutron cross sections of many heavy nuclei, with atomic weights of from 100 to 238 and in the energy range of a few to several hundred electron volts, were measured with the high resolution "fast chopper," which is a device for separating neutrons of different energy ranges. The strengths of the interaction of resonance energy neutrons and nuclei were determined from these total cross section measurements—particularly for the rare earth elements having atomic weights near 160—in testing theoretical models of the nucleus. The results obtained agreed with recent concepts of nuclear models, predicting a stronger interaction in this atomic weight region than older theories which predicted a value independent of atomic weight. Total cross section measurements in the resonance energy region with the "fast chopper" and crystal spectrometer were also analysed to determine the capture of resonance neutrons for many of these heavy nuclei. The constancy of capture width for various resonances for a single isotope, its decrease with increasing atomic weight, and its unusually high values for isotopes having close to 126 neutrons were established. Measurements with the crystal spectrometer of the scattering of neutrons and activation cross section also yielded additional information on the interaction of neutrons with nuclei.

The Los Alamos Scientific Laboratory facilities for measuring cross sections of concern to the nuclear weapons and reactor programmes of the A.E.C. have approached the planned goal of having available sources of fast neutrons covering a wide range of energy. The large Van de Graaf electrostatic accelerator, which is now able to accelerate particles to 6·5 MeV, was in routine use. Its most important function was to produce neutrons of energies greater than 5 MeV for fission, scattering, activation and gamma-ray measurements in a relatively unknown energy region of great value in reactor, shielding and weapons calculations.

One of the 2·5 MeV accelerators at Los Alamos provided intense neutron sources from a few thousand electron volts to several MeV, permitting the measurements of fission cross sections and neutron scattering experiments in the range in which a large fraction of the neutrons are emitted in fission. An intense source of 14 MeV neutrons produced by the deuterium-tritium reaction was obtained from a 250keV accelerator. Measurements similar to those at lower energies were made, but the large number of neutrons generated per second was of particular advantage in shortening the exposure times and for obtaining radio-chemical samples. This 250keV Cockcroft-Walton accelerator will soon be replaced by a larger, 600keV accelerator. Since charged nuclei are also involved in neutron reactions, a second 250keV accelerator was used primarily for studies of charged particle reactions at very low energies and for investigating the passage of protons or deuterons through matter. Similar emphasis was placed on measuring cross sections for interactions of tritium nuclei, accelerated with other charged particles by a 2·5 MeV accelerator.

It has been established that high-energy particles and gamma rays emitted in fission, or by radioactive elements, promote chemical reactions in water. An understanding of such reactions is useful in view of their application to fundamental chemical and biological research and to the development of reactors using water as a coolant or moderator. Upon striking the water these high-energy particles lose energy along their tracks. This energy is transferred to the water, decomposing it into stable molecular products (hydrogen and hydrogen peroxide) and into extremely reactive, short-lived hydrogen and hydroxyl free radicals. At the Argonne National Laboratory methods were devised for measuring the yields of these stable products and free radicals produced along the tracks of the particles. Results showed that stable products predominate for heavy particle radiations, such as alpha rays and fission fragments, whereas free radical production predominated for gamma rays and beta particles. However, it has been found that the average energy required for water decomposition into these products does not depend on the nature of the particle. In liquid water the free radicals hydrogen and hydroxyl are able to exist for only a split second and have never been detected, although their presence as transient species has long been assumed to explain the kinetics of the radiation effects. However, in ice irradiated at low temperatures these intermediates would be expected to be more stable. Substantial evidence for the existence of hydrogen and hydroxyl radicals in irradiated ice was obtained for the first time using the very sensitive method of observing their absorption of radio-frequency power when the irradiated ice is placed in a magnetic field. At the Oak Ridge National Laboratory, atomic hydrogen, i.e. free radical hydrogen, was discovered to exist in the solid state. It was produced by irradiating with gamma rays from cobalt 60 frozen samples of perchloric, sulphuric and phosphoric acids cooled down to liquid nitrogen temperatures. Identification was made by the use of micro-wave spectroscopy techniques and confirmed by independent observation.

Theoretically the magnetic behaviour of ferrites has generally been explained by assuming the existence of several interactions or coupling arrangements between individual atomic magnets. The dominant interaction has the effect of aligning the atomic magnets into two opposing and non-compensating groups. Many interesting consequences of this picture were verified by earlier neutron diffraction experiments at the Oak Ridge National Laboratory and the Brookhaven National Laboratory. Recent experiments at Brookhaven have now demonstrated the existence of one of the postulated subsidiary interactions in zinc ferrite where the dominant interaction is absent. Since this interaction is weak, it is necessary to perform the experiments at temperatures sufficiently low to overcome the masking effect of the thermal vibrations normally present at high temperatures. In these experiments neutron diffraction patterns of zinc ferrite were obtained by using special equipment at temperatures a few degrees above absolute zero.

Although helium 3 occurs rarely in Nature, experimental quantities of this stable isotope were produced in nuclear reactors through the reaction of neutrons with lithium. Radioactive tritium, which eventually decayed into helium 3, was first obtained. This source of helium 3 made possible a wide variety of studies of the properties of liquid helium at temperatures near absolute zero. Scientists at the Argonne National Laboratory recently measured the specific heat of liquid helium 3 at temperatures down to within 0·42 deg. of absolute zero. Results indicated that above this temperature nuclear interactions are not sufficiently dominant to cause nuclear spins in liquid helium 3 to line up in an ordered fashion. The effect of nuclear interactions is considered to be important in attempts to explain the unusual properties encountered in certain materials near the absolute zero of temperature, such as the disappearance of fluid friction (super-fluidity) and of electrical resistivity (super-conductivity). Related work at other laboratories on the magnetic susceptibility of liquid helium 3 indicates, however, that the nuclear effects do begin to be noticeable at temperatures only slightly lower than 0·42 deg. absolute.

Plant for the Manufacture of Tractors and Graders at Decatur

A NEW factory for the manufacture of wheeled tractors and motor graders is at present under construction for the Caterpillar Tractor Company at Decatur, Illinois. The factory is being built on a 423-acre site, and will be 855,000 square feet in extent. It forms part of an expansion programme costing 45,000,000 dollars, which also includes modifications in the production of crawler vehicles and diesel engines at the company's parent works at Peoria. Constructional work at Decatur had advanced sufficiently for 30 per cent of the steelwork to have been erected early in September; much of the foundation concrete had been poured by that time, and the heating plant was nearing completion. It is expected that the first manufacturing plant will be installed in the new factory at Decatur in February, 1955, and full production will be achieved in about eighteen months time in the Spring of 1956.

Industrial and Labour Notes

Technical Colleges and Industry

Last May, the Federation of British Industries convened a conference to discuss the relationship between technical colleges and industry. The programme was drawn up by a committee consisting of the principals of three technical colleges and three members of the F.B.I. education committee, and the discussions at the conference were introduced by technical college and industrial speakers.

The F.B.I. has now published a full report of the proceedings. No formal resolutions were made at the conference, but the report includes a statement about the main conclusions which emerged from the discussions. This statement says that the functions of the technical colleges are not, in general, fully understood, even in industry. This, it is suggested, is partly due to a confusing terminology, but mainly to the wide range of work the colleges undertake. It is not always appreciated, the statement continues, that within this range there are three main educational levels, the craft, the technical and the technological levels. The majority of technical colleges are concerned with craft and technical education, and a minority with technological education.

Another conclusion drawn from the conference discussions was the need for closer co-operation between the technical colleges and industry, particularly on a local basis. The F.B.I. report says on this point that, however effective co-operation may be at the national and regional levels, substantial progress will be achieved only through co-operation between the individual technical college and the industries in the area it serves.

Engineering Wages

At a meeting of the executive council of the Confederation of Shipbuilding and Engineering Unions, which was held at York on Thursday of last week, it was decided to put forward claims for further increases in the wages of engineering and shipbuilding workers. It is stated that the claims are to be 15s. a week for skilled and 10s. a week for unskilled men in the engineering and shipbuilding industries. These claims are to be submitted to the Engineering and Allied Employers' National Federation and the Shipbuilding Employers' Federation. The Engineering Employers' Federation is to be asked to discuss the grading of skilled and unskilled workers, and a discussion on a revision of holiday agreements is to be sought with both the employers' federations.

It may be recalled that at the annual conference of the Confederation of Shipbuilding and Engineering Unions, in August last, a resolution was passed urging that negotiations should be started for the establishment of a new wages structure in the engineering industry. This resolution also urged "new wages scales which would provide substantial pay increases for all grades of workers in the industry." It has been stated, however, that the new claims, decided upon last week by the Confederation's executive, are to be based upon the increase in the cost of living, improved production and the continued rise in profits.

Railway Wages

At the end of last week it was announced that agreement had been reached between the British Transport Commission and the unions on a new wages structure for the employees of British Railways. The negotiations have been going on intermittently since last December, when a wage increase of 4s. a week, awarded by the Railway Staff National Tribunal, was accepted as an interim measure. Further increases were made in January which, with the 4s. a week award, represented a general wage increase of 6 per cent. The agreement which has now been reached is a third and final stage in the negotiations. Its application means that, compared with the rates prevailing last December, increases are to be made ranging from 7s. 6d. to 16s. 6d. a week for operating grades and from £13 to £70 15s. a year for male clerical staff. Wage claims made by the Associated Society of Locomotive Engineers and Firemen, in respect of footplate men, are, however, still outstanding and await arbitration by the Railway Staff National Tribunal.

A second agreement between the British Transport Commission and the three unions is concerned with railway efficiency. A statement issued last Friday said that the representatives of the Commission and the unions reiterated their determination that every possible step should be taken to improve the efficiency of the railway industry. To that end, the union representatives agreed that appropriate advice be sent to their members of the Commission's intention to arrange for meetings to take place within the next four weeks of all the local representatives of the staff with the appropriate officers of the railway regions. Such meetings would consider any outstanding questions concerning the increase of efficiency. It was recognised, the statement added, that there might be some aspects of working or of arrangements which would need consideration at a higher level if efficiency was to be obtained, and discussions at national level would be arranged to deal with such questions where appropriate.

Economic Review

In the latest issue of *Bulletin for Industry*, the information division of the Treasury has presented a general review of this country's economic situation. It says that the United States recession has not caused world prices and trade to weaken, as seemed likely early in the year, and that in this country production and employment have risen, export demand has been firm and consumers' expenditure has continued to increase.

In the second quarter of this year, the *Bulletin* records, industrial production was running about 2 per cent above the fourth quarter of last year. Most industries have increased their output, with the biggest contributions to the total rise in the first half-year coming from engineering, which was 6 per cent higher than a year earlier; vehicles, 12½ per cent higher, and paper and printing. In the chemical industries there was a big increase in output, and in the textile industries output was "steady." Coal output, the review adds, has been disappointing, although the figures for the last three months suggest some rise in deep-mined output. Other matters mentioned in the review are that wage rates in July were on average about 3 per cent higher than in December last year; output per man in the second quarter of this year was about 4 per cent above the average for 1953; and that, judged by reports published in the first seven months of this year, profits of industrial companies in the year ended December last were about 10 per cent up on the preceding year.

The review says that no up-to-date figures about industrial investment are available. What evidence there is, however, suggests that while there has been no increase in deliveries of plant and machinery to the home market, there has been a rise in the flow of new orders. These fell sharply from 1952 to 1953, although there was a steady rise during the latter year. In the first half of 1954 there was no further rise, and the volume of new orders appears to have settled at around the 1950 level. This, the *Bulletin* says, marks a substantial improvement on 1953 as a whole.

Employment and Unemployment

In its latest report on the employment situation in Great Britain, the Ministry of Labour states that at the end of August the total working population numbered 23,691,000. The number in civil employment was 22,621,000 (15,019,000 men and 7,602,000 women), which was 103,000 more than at the end of July. The increase was, of course, due mainly to the entry into employment of boys and girls who had left school.

An analysis of civil employment in August shows that 4,043,000 people were at work in the basic industries of the country. That was 15,000 above the total returned a month earlier, the whole of the increase being a seasonal one in agriculture. There was no change in the manpower figure for the collieries, which at the end of August remained at 706,000, compared with 712,000 a year earlier. The manufacturing industries added 64,000 to their labour forces during August, the total at the end of the month being 9,092,000. The biggest increase in those industries was in the "engineering, metal goods and precision instruments" group, which added 24,000 to its labour force, making a total at the end of August of 2,659,000, compared with 2,564,000 a year earlier. An additional 9000 people were taken into employment in the vehicle building industries during August, bringing the total to 1,183,000. Outside the basic and manufacturing industries, there was an increase of 3000 in August in the number employed in building and contracting, the total by the end of the month being 1,428,000.

The Ministry of Labour says that in the week ended August 28th there were 33,600 people working short time in manufacturing establishments, each losing twelve hours on the average. This figure was about 10,000 below the total at the end of May. On the other hand, in the last week of August, 1,509,000 operatives were working on an average eight hours' overtime. On September 13th, there were 236,027 people registered as unemployed, compared with 239,609 on August 9th. The September figure, which represented 1·1 per cent of the total number of employees, included 43,965 married women and 9303 people described as "temporarily stopped."

Overseas Trade

The Board of Trade states that exports of United Kingdom goods in September have been valued provisionally at £210,500,000, bringing the monthly average for the third quarter of this year to £221,000,000. This was about 1 per cent below the monthly average for the first half of this year, but was 4½ per cent above the average for the third quarter of 1953. Re-exports in September, in which there were twenty-six working days, have been valued at £6,200,000, making the monthly average for the third quarter £7,800,000. The value of imports into the United Kingdom in September has been put at £285,800,000, the monthly rate for the third quarter being £280,100,000. The Board of Trade says that this was slightly more than in the first half of this year, and 2 per cent above the monthly rate in the third quarter of 1953. The excess of imports over total exports averaged £51,300,000 a month in the third quarter, compared with £54,800,000 a month in the corresponding quarter of 1953.

Industrial Expansion

On Thursday of last week the annual general meeting of the East and West Ridings members of the Federation of British Industries was held at Sheffield. The meeting was addressed by Sir Harry Pilkington, president of the F.B.I., who urged that, nationally, we should plan for more and more expansion. He said that we were undergoing a new industrial revolution on a scale that many people still did not realise. Capital expenditure was needed to supplement the efforts of our numerically static working population if we were to get the great increase in output and productivity that would raise the living standards of people here and overseas. Both in the public and private sectors of finance, Sir Harry continued, capital expenditure for productive purposes "must proceed in parallel." It was no good industry spending money on machinery if there was going to be neither coal mined nor power stations built to supply the means to drive those machines. Nor was it any good, Sir Harry added, in the public sector, building power stations to supply industry if it was made impossible by taxation for industry to finance its modernisation and expansion, or for its customers to buy its products.

Notes and Memoranda

Rail and Road

BRITISH RAILWAYS' DIESEL RAILCAR EQUIPMENT.—As a further step in the programme for the development of multiple-unit, lightweight diesel passenger trains, British Railways have placed a contract with British United Traction, Ltd., for forty-three sets of power equipment and twenty-one sets of trailer-car equipment. Each power car will embody two 150 h.p. diesel engines with mechanical transmission. The cars for which these power equipments are intended will be designed and built at Swindon Works. With this contract British Railways have now made a total expenditure of over £3,000,000 on lightweight diesel development.

Air and Water

OCEANOGRAPHIC CONFERENCE.—We are informed that a Commonwealth Oceanographic Conference is to be held at the National Institute of Oceanography at Wormley, near Godalming, Surrey, from October 18th to 22nd. The conference is to study the possibility of closer co-operation in oceanographic research throughout the Commonwealth. The Royal Research Ship " Discovery II " will be at No. 22 Berth, Eastern Dock, London Dock, so that conference delegates can inspect the ship and her equipment.

LLOYD'S WRECK RETURNS.—Lloyd's Register of Shipping has issued its *Statistical Summary of Merchants' Ships Totally Lost, Broken Up, &c., during* 1953. The world total of steamships and motorships lost consequent upon casualty amounted to 223 ships of 303,459 tons gross, of which 30 ships of 66,506 tons belonged to Great Britain and Northern Ireland, and 30 ships of 18,026 tons to the other Commonwealth countries. The corresponding figures for ships lost not consequent upon casualty were respectively : 413 ships, of 1,132,853 tons ; 129 ships, of 380,300 tons, and 34 ships of 77,557 tons. In addition to giving totals of individual nations the summary includes a list of ships lost consequent upon casualty since 1929.

Miscellanea

MR. W. MORRIS SMITH.—We regret to record the death of Mr. W. Morris Smith, which occurred suddenly at his home at Elderslei, Renfrewshire, on Saturday, September 25th. Mr. Smith, who was fifty-five years of age, was the chief engineer of Joy-Sullivan, Ltd.

OIL SURVEY.—A geophysical survey will be started next month in the waters off the Persian Gulf territory of Abu Dhabi, on behalf of the Anglo-Iranian Oil Company, Ltd., and the Compagnie Française des Petroles, using underwater seismic surveying technique.

DRILLING FOR OIL IN LEICESTERSHIRE.—We are informed by the Anglo-Iranian Oil Company, Ltd., that the D'Arcy Exploration Company has begun drilling for oil at Hathern, near Loughborough, Leicestershire, and that a second drilling rig engaged at Bottesford, east of Nottingham, has reached a depth of 2783ft.

CORRECTION.—In the note on a " Muir-Hill " shunting tractor made by E. Boydell and Co., Ltd., of Manchester, which appeared in our issue of September 17th, we inadvertently stated that it was a flame-proof machine. The makers point out that although this machine was specially designed to reduce considerably the risk of ignition of petroleum vapour in the atmosphere it is not claimed to be " flame-proof."

COAL BOARD'S STAFF COLLEGE.—The National Coal Board has decided to establish a staff college for the mining industry and has appointed Mr. N. G. Fisher, M.A., who is at present chief education officer to the City of Manchester Education Committee, to be its principal. Mr. Fisher will take up his duties early in 1955. The staff college will provide a centre for courses and conferences for the Board's senior staff, and will enable the work which has already been done in this field of management training to be further developed. Mr. G. Essame, who has been directing the Board's existing courses, is to be the director of studies at the college.

EXTENSION OF TELEVISION TRANSMISSION.—The B.B.C. announces that the television station at Rowridge, Isle of Wight, will start test transmissions on Monday, October 18th, and will be fully brought into service on November 12th. Test transmissions will be daily (except Sundays) from 10 a.m. to 1 p.m. The frequencies used are 56·75 Mc/s for vision and 53·25 Mc/s for sound (channel 3). The temporary station at Truleigh Hill, which operates on the same wavelengths, will stop its morning test transmissions during this period, but will continue daily after 1 p.m., until November 12th, when it will be closed down. Initial range of the Rowridge transmitter is expected to cover the area Brighton to Bridport and inland as far as Devizes and Newbury. When the permanent 500ft mast is completed in a year's time, the service will be extended to Seaford in the east, Seaton in the west, and Lambourn in the north.

INSTITUTE OF WELDING.—The autumn meeting of the Institute of Welding will be held in London from October 27th to 29th, the first event being the annual dinner at the Park Lane Hotel, Piccadilly, W.1, on October 27th, at 7 for 7.30 p.m. The technical sessions are to be held at the Institution of Civil Engineers, Great George Street, Westminster, S.W.1, beginning at 10.30 a.m. on Thursday, October 28th, when Mr. R. G. Braithwaite, M.I.C.E., will deliver his presidential address. It will be followed by a paper entitled " A New Process of Stud Welding," by Mr. W. P. van den Blink, Mr. E. H. Ettema and Dr. P. C. van der Willigen. At an afternoon session at 2.30 p.m., the two following papers will be discussed :— " The Automatic Argon Arc Welding of Low Alloy Steel Sheet," by Mr. F. J. Wilkinson, and " The Twin Argon Welding Process," by Mr. J. A. Donelan. The final session of the meeting will begin at 10.30 a.m. on Friday, October 29th, when the papers to be presented are : " Vanadium as Replacement for Molybdenum in Low Alloy Steels," by Dr. C. L. M. Cottrell and Mr. B. J. Bradstreet ; " Weldability of a B–Mo Steel related to the Properties of the Heat-Affected Zone," and " Weldability of Mn–Mo Steel related to the Properties of the Heat-Affected Zone," by Dr. C. L. M. Cottrell. Tickets are not required for the technical sessions.

TWO ENGINEERING FILMS.—Two new technical films, " Casehardening and Heat-Treatment of Steel in ' Cassel ' Salt Baths " and " Metal Degreasing by Trichlorethylene " were recently shown for the first time at Birmingham by Imperial Chemical Industries, Ltd., to representatives of the many engineering firms which co-operated in the making of the films. The films demonstrate the plants and processes for casehardening, heat-treatment and degreasing provided by the General Chemicals Division of I.C.I., and are intended for showing to engineering audiences, both in this country and abroad. Most of the heat-treatment film was taken in the I.C.I. heat-treatment department at Oldbury, but many scenes were made in the works of firms using I.C.I. processes. Similarly, much of the other film was taken at the company's degreasing department at Runcorn, but a number of other firms provided facilities for scenes to be made in their works.

EUROPEAN COAL PROSPECTS.—The coal trade subcommittee of the United Nations Economic Commission for Europe has recently met to review the solid fuel situation for the fourth quarter of this year. The discussions showed that difficulty might be experienced by some European exporting countries in covering all the demands made upon them by importers. It was stated that considerable tonnages of coal were in stock in Belgium and in France/Saar, but the question arose, outside any commercial considerations, as to whether in the present situation of the market all qualities in stock were likely to interest consumers and also to what extent the lifting of those qualities could be done without difficulty. There existed also important stocks of coke at coke ovens in Western Germany. Figures submitted by experts attending the meeting showed that an increase in demand was anticipated in all countries. Most of this would be seasonal, but there were also increases in coke oven requirements, evenly spread amongst coke-producing countries, which could not be wholly attributed to seasonal factors and might be a forerunner to a more general expansion in demand.

I.MECH.E. CROSSLEY SCHOLARSHIP.—The Institution of Mechanical Engineers has stated that, under the terms of the Bate Crossley bequest, the council is able to make an award to the author of a paper on a subject relating to British-made machine tools. The sum of money at the disposal of the council is sufficient to meet the full maintenance costs of one student at an establishment of full-time education for a period of three years. The council may, however, make smaller awards to more than one person, should the circumstances warrant this. The council has decided to award the scholarship on the results of an essay competition, the conditions of which are : candidates for the C. W. Bate Crossley scholarship are required to submit an essay on a subject bearing upon the design and use of British-made machine tools ; they should not cover too wide a field, but should confine their treatment of the subject to a limited number of selected machine tools or to certain aspects of machine tools ; essays, which must not exceed 5000 words in length, should reach the Secretary not later than May 1, 1955 ; the scholarship will be tenable at a university or technical college or other establishment of full-time education in the United Kingdom, the choice of establishment being in the discretion of the council who will take into account all the circumstances of the particular case, including the candidate's proposal ; candidates must be students or graduates of the Institution and must be under twenty-five years of age on June 30, 1955 ; the council will appoint an adjudication committee to judge the essays and this committee may require selected candidates to attend for interview. The committee will take into consideration the potential benefit to be derived from further full-time education by those candidates selected for interview, and will invite each candidate so selected to submit proposals regarding the full-time course of study he would pursue if awarded a scholarship.

Personal and Business

MR. J. S. SPENCER has been appointed a director of British Combustion Equipment, Ltd.

FINNAIR has established a London office at 121, Ebury Street, S.W.1 (telephone, Sloane 7555).

MR. B. H. DOUTHWAITE has been appointed sales manager of British Physical Laboratories, Radlett, Herts.

AIR COMMODORE F. R. BANKS, C.B., F.R.Ae.S., has been elected a director of the Bristol Aeroplane Company, Ltd.

SAMUEL MARSDEN AND SON, Ltd., Altrincham Street, Manchester, has acquired the business of Edward Mercer, Ltd., Hollinwood, Lancs.

THE INTERNATIONAL HARVESTER COMPANY, Chicago, announces the appointment of Mr. Brooks McCormick as director of manufacturing.

PRIESTMAN BROTHERS, Ltd., Hull, announces the retirement of Mr. S. J. Smith from the position of London manager. His successor is Mr. N. H. Josephy.

COMMANDER (E) T. F. CRANG, R.N. ret., has been appointed head of the research and development department of J. Samuel White and Co., Ltd., Cowes, Isle of Wight.

D. NAPIER AND SON, Ltd., Acton, London, W.3, announces the appointment of Rear-Admiral (E) W. G. Cowland, C.B., as deputy chief engineer in its gas turbine division.

UNITED DOMINIONS TRUST, Ltd., states that, from November 1st, its address will be United Dominions House, Eastcheap, London, E.C.3 (telephone, Mansion House 8744).

MR. J. D. VAUGHAN, M.I.C.E., has been appointed a director of Horseley Bridge and Thomas Piggott, Ltd. Mr. R. J. Fowler has succeeded Mr. Vaughan as chief engineer of the company.

KODAK, Ltd., Wealdstone, states that Mr. E. E. Blake has relinquished the chairmanship of the board. He will continue to serve as a director. Mr. H. S. Carpenter has been appointed chairman and Mr. I. D. Wratten has been appointed a deputy managing director.

MR. GEOFFREY KENNEDY, M.I.Mech.E., M.I.E.E., has been appointed by Electricite de France as a member of the Comite Consultatif des Usines Maremotrices, which has been established for the French tidal power schemes of the Rance and Chausey Mont Saint-Michel.

MONKS AND CRANE, Ltd., Stanhope Street, Birmingham, 12, states that Mr. D. W. Thomas has been appointed joint managing director. Mr. A. H. Barton, commercial manager, and Mr. V. G. Eyre, general sales manager, have been appointed directors.

BRITISH TYRE AND RUBBER COMPANY, Ltd., announces the retirement of its chief buyer, Mr. E. Waterworth, after more than forty years in the company's service. The company announces also the retirement of Mr. J. Haseltine from the sales staff of India Rubber, Gutta Percha and Telegraph Works Company, Ltd., after fifty-two years' service.

SIR KENNETH HAGUE, deputy chairman and managing director of Babcock and Wilcox, Ltd., has relinquished the chairmanship of the associated company, Edwin Danks and Co. (Oldbury), Ltd., owing to other commitments. General Sir Kenneth Crawford, K.C.B., has been appointed a director and chairman of Edwin Danks and Co. (Oldbury), Ltd.

THE GENERAL ELECTRIC COMPANY, Ltd., announces the retirement of Mr. F. R. Unwin, M.I.E.E., manager of the instrument and switchgear department. His successor is Mr. J. Lawrence, formerly assistant district manager for the N.W. area at the Manchester office. Mr. E. G. Taylor, M.I.E.E., has succeeded Mr. Lawrence at the Manchester office. Mr. H. W. Roberts, A.M.I.E.E., manager of the Blackburn branch, has retired, his successor being Mr. H. F. North, formerly branch engineer at Sheffield. Mr. L. D. Goldsmith, F.R.I.C., manager of the G.E.C. battery works at Witton, has retired after thirty-nine years with the company. His successor is Mr. J. A. Walters.

LONDON TRANSPORT states that, following the retirement of Mr. F. A. A. Menzler, chief development and research officer, that post is discontinued. Mr. A. T. Wilford, director of research, now reports to the Executive through the chairman, and Mr. H. E. Styles, superintendent of laboratories, has been appointed an officer of the Executive ; Mr. J. D. C. Churchill, planning officer, now reports to the secretary. In the department of the chief civil engineer, Mr. E. W. Gain, A.M.I.C.E., senior executive assistant in the office of the new works engineer, has been appointed a principal executive assistant, and Mr. J. E. W. Hanscomb, senior executive assistant, has been appointed principal executive assistant responsible for co-ordinating the activities of the works and building section.

Launches and Trial Trips

'BORDER MINSTREL, oil tanker ; built by the Blythswood Shipbuilding Company, Ltd., for the Lowland Tanker Company, Ltd. ; length between perpendiculars 515ft, breadth 69ft 6in., depth moulded 37ft 6in, deadweight 16,000 tons ; twenty-seven cargo oil tanks, two cargo oil pump rooms, four 500-tons per hour cargo oil pumps ; Rowan-Doxford two stroke oil engine, six cylinders, 670mm diameter by 2320mm combined stroke, 6800 b.h.p., two oil-fired Scotch boilers.—Launch, August 31st.

KENIA, oil tanker ; built by the Netherlands Dock and Shipbuilding Company, Amsterdam, for N.V. Petroleum Maatschappij " La Corona " ; length overall 170m, length between perpendiculars 161·54m, breadth moulded 21·11m, depth 11·89m, deadweight 18,000 tons on 8·99m draught ; thirty-three cargo oil tanks, speed 14½ knots ; single set of Pametrada turbine machinery built by N.V. Werkspoor, Amsterdam, 8300 s.h.p., two Babcock and Wilcox boilers.—Launch, September 18th.

FREDERICK T. EVERARD, coaster ; built by the Goole Shipbuilding and Repairing Company, Ltd., for F. T. Everard and Sons, Ltd. ; length 285ft, breadth 42ft, depth 19ft 3in ; diesel engine built by the Newbury Diesel Company, Ltd., 1600 b.h.p. at 250 r.p.m.—Trial, September 21st.

VESTVARD, oil tanker ; built by Smith's Dock Company, Ltd., for Klosters Rederi A/S ; length overall 555ft 9in, length between perpendiculars 530ft, breadth moulded 71ft, depth moulded 39ft, deadweight 17,900 tons on 29ft 6in draught, service speed 14·25 knots ; twenty-seven cargo oil tanks, two cargo oil pump rooms, four 500 tons per hour cargo oil pumps, steam deck machinery, two 50kW steam-driven generators and one 50kW diesel-driven generator ; Harland and Wolff-B. and W. single-acting, two-stroke, opposed piston diesel engine built by John G. Kincaid and Co., Ltd., seven cylinders, 750mm diameter by 2000mm combined stroke, 7600 b.h.p. at 110 r.p.m., two Scotch marine boilers. Launch, September 27th.

British Patent Specifications

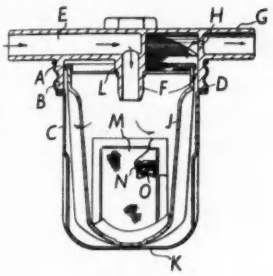
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. 8d. each.

INTERNAL COMBUSTION ENGINES

715,454. November 24, 1952.—WATER-CONDITIONING APPARATUS, Fram Corporation, 55, Pawtucket Avenue, East Providence, Rhode Island, U.S.A. (*Inventors: Elliot Josselyn Parker* and *Clarke Alden Rodman.*)

The invention relates to a water conditioner particularly designed for use in the cooling system of an internal combustion engine. The unit, as shown in the drawing, comprises a head *A*, of cast construction, having screw threads at *B* on which there is assembled a cylindrical casing *C*, usually of thin metal screwed on to the threaded portion of the head to form a tight seal through gasket *D*. An inlet conduit *E* is provided in the head leading to an extending inlet nozzle *F* and there is an outlet conduit *G* with a restricted passage *H* which also may be used for control of the proportion of the circulating water by-passed through the casing. A cup-shaped cartridge or shell *J* is corrugated so as to increase its exposed surface and also to stiffen it, and is formed of moulded paper pulp impregnated with resinous material through which water may readily flow. This moulded paper serves



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as a filter to permit the passage of water, but also to collect within it any solid particles which may be in the coolant which flows through the system. This cartridge has a top wall with an opening to receive the inlet nozzle *F* and is supported on the bottom *K* of the casing so that the top wall engages a shoulder *L* on this nozzle and maintains the cartridge centred with respect to the casing. Liquid entering through the nozzle *F* will pass through the cartridge and then upwards along the inner surface of the casing and out through the restricted opening *H* and discharge conduit *G*. In order that the water which passes through this cartridge may be chemically treated, a fabric bag *M* through which water may readily pass is provided and within this bag is placed an ion exchange softening material *N*, which material reacts with the water to remove the components which would otherwise be thrown out of solution by heating the water and collect upon the walls of the water-cooling system. A corrosion inhibitor is also placed in the bag *O* so as to prevent corrosion within the cooling system. In the course of an extensive investigation, softeners of the phosphate, borate and polyamino carboxylic acid salt types, and ion exchange materials of the natural zeolite types and polystyrene, divinyl, benzene sulphonic, phenolic sulphonic and carboxylic resin types, and corrosion inhibitors of the chromate, borate, nitrite, silicate and soluble oil types, including the borate and mercaptobenzo thiazole types, have been successfully used.—*September* 15, 1954.

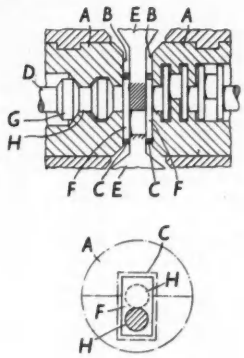
715,281. October 16, 1951.—AUXILIARY GAS TURBINE PLANT FOR INTERNAL COMBUSTION ENGINES, Schweizerische Lokomotiv-und Maschinenfabrik, Winterthur, Switzerland.

The invention relates to a method of preventing damage to the auxiliary gas turbine plant, i.e. a supercharging compressor coupled to an exhaust-gas-driven turbine of an internal combustion engine for driving a vehicle, when the vehicle is coasting and power output is not required. According to the invention at least one of the blade wheels can be supplied with pressure gas from a reservoir when the fuel supply to the internal combustion engine is cut off, and it is characterised in that the supply of pressure gas is sufficient only to overcome the frictional resistances of the relatively movable parts of the plant at slow speeds in order to prevent damage to the gas turbine plant by external shock loads. According to a further feature the pressure gas is preferably applied to the compressor blading. By utilising the method the auxiliary plant may be kept in motion and hence be less liable to damage by external shocks, with the use of a pressure gas applied to either the compressor or the turbine blade wheel of a gas turbine. The compressor is preferably supplied with pressure gas, since its blades do not reach elevated temperatures as do those of the turbine which might be damaged if rapidly cooled.—*September* 8, 1954.

METALLURGY

715,356. February 19, 1952.—APPARATUS FOR FORGING CRANKSHAFTS, English Steel Corporation, Ltd., River Don Works, Sheffield, 9, and George Shewan Cleghorn, of the company's address.

The invention relates to apparatus for forging crankshafts, the apparatus being of the general kind described in the prior Specification No. 622,938. One object of the invention is to provide apparatus for forging crankshafts from blanks wherein the inner



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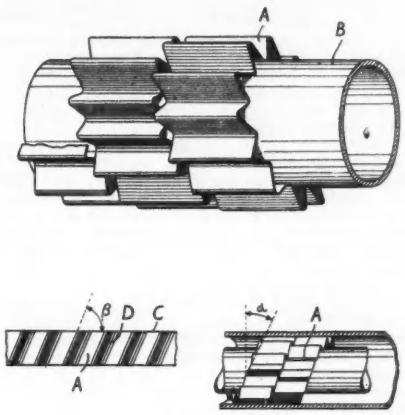
face of an end die is formed or provided with one or more metal projections which are so shaped and positioned that, during a forging operation, the flow of the blank metal between the end die and the central die is constrained in a direction normal to the axis of the blank for the purpose of producing a crank web having the required shape. Referring to the drawing, the end dies *A* have their inner end faces *B* modified by the provision of metal projections *C* which extend perpendicularly from the respective end faces. The projections are shaped to provide on each end die inner face *B* a continuous rectangular rim. These rims are positioned respectively to surround those parts of a blank *D* which lie immediately adjacent each side of the central die *E* and which are deformed into webs *F* by a forging operation. The blank *D* is intended for the production of a crankshaft having multiple crank throws, the blank in its unforged condition consisting of a number of swells *G* separated by necks or constrictions *H*, and, in this condition, being shown gripped in the die *A*, which is on the left-hand side of the apparatus. The die *A* which is on the right-hand side is shown gripping a forged part of the blank *D*. It will be appreciated that the web parts *F* of the crankshaft which are produced by the forging operation are constituted by the swells *G* prior to the forging operation. The projections *C* may be formed integrally with the respective end die inner faces *B* or they may be fixed to them in some other convenient manner. Further, each end die inner face may have a single projection shaped to form a rim, or such rim may be composed of a number of projections. In operation, the flow of the swells in a direction normal to the longitudinal axis of the blank, and between the end die inner faces *B* and the adjacent side walls of the central die *E*, is constrained or controlled by the metal projections *C*, so that the webs produced each have a final rectangular form in plan which corresponds in shape to the area bounded by the associated projection rim. The necessity of machining these webs down from an elliptical form to produce a rectangular shape is thus entirely eliminated. Webs of any desired shape can be made.—*September* 15, 1954.

HEAT EXCHANGERS

715,598. December 17, 1952.—HEAT EXCHANGER TUBES, Escher Wyss Aktiengesellschaft, Hardstrasse 319, Zurich, Switzerland.

The invention relates to heat exchanger tubes for use in circumstances where the heat transfer at the inner and/or outer surfaces of the tubes takes place by forced convection. The aim of the invention is to achieve an intimate heat exchange between two flowing media in a more economic manner than hitherto by simply constructed means. In the constructional form shown in the drawing, a helix of corrugated metal strips *A* is arranged on the external surface of the tube *B*. As shown in the lower view, the pitch angle α of the helical strip is complementary to the angle β formed by the edge *C* of the strip and the flanks *D* of the corrugations. An external tube is pushed over the metal strip to force it into intimate contact with the internal tube. The relation of the diameter of the tube *B* to the distance between the



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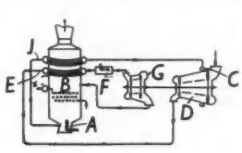
peaks or troughs of consecutive corrugations of the metal strip *A* is such that the corrugations of adjacent convolutions of the strip are staggered relatively to one another in the peripheral direction of the tube, the flanks of the corrugations extending parallel to the tube axis. As a consequence the ducts defined by the external tube surface and the flanks of the corrugations also extend parallel to the tube axis in the direction of the flow existing on the outside of the tube. Since the ducts after each convolution are, as already mentioned, staggered in the circumferential direction, as clearly shown in the upper view, the boundary layers formed on the surface of the metal strip *A* are periodically interrupted. This substantially contributes to the production of a good heat transfer. Owing to the fact that the flanks of the corrugations are disposed parallel to the tube axis, there is also ensured a good contact between the troughs of the corrugations and the external surface of the tube along the entire generatrices of the corrugation surface.—*September* 15, 1954.

STEAM GENERATORS

715,807. October 5, 1949.—STEAM GENERATORS WITH SUPERCHARGED FURNACES, Societe Rateau, 40, Rue du Colisée, Paris, Seine Department, France, and René Anxionnaz, a citizen of the French Republic, of 8, Rue Nicolas Chuquet, Paris, Seine Department, France. (*Inventor: Raymond Francois Maurice Waeselynck.*)

In the design shown in the drawing, the air required for combustion inside the furnace *A* of the steam-generator *B* is taken from an intermediate stage *C* of the air compressor *D*. This discharges at a high pressure the remainder of its flow through a heater *E* which is located in the heating circuit of the generator



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and heated by gas supplied by the furnace *A*, and then through a turbine combustion chamber *F* in which is burned a liquid fuel. The heater *E* is not indispensable and the combustion chamber *F* only may be provided. By the combustion chamber it is possible to impart to the air an adjustable amount of heat enabling the adjustment of the power supplied by the gas turbine *G* connected to the outlet of chamber *F* and hence, the flow of air discharge by the compressor *D* driven by the turbine. The gas expanded inside the gas turbine *G* is exhausted into an intermediate stage of the gas circuit of the generator *B* at slightly above atmospheric pressure. The furnace *A* is supercharged at the pressure of the intermediate stage *C* of the air compressor and not at the maximum pressure of the last stage of the compressor. The arrangement described enables the addition to the combustion air circuit, to the steam generator, of a low temperature heater *J*, heated by the residual heat of the flue gas of the generator. Two other modified circuits are also given in the specification.—*September* 22, 1954.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street London, W.1.

ENGINEERS' COMPARATORS FOR EXTERNAL MEASUREMENT

No. 1054 : 1954. Price 2s. 6d. Many advances in the design of measuring instruments have been made since this standard was first published in 1942, and comparators are now made with magnification factors of 10,000 and over. The standard has, accordingly, been revised to include provisions for these more sensitive instruments and the opportunity has also been taken to clarify certain of the general requirements.

As development in this field is a continuous process and it would be unsuitable to lay down design requirements which might have a restrictive effect, the standard is mainly concerned with such features of the instrument as are essential to enable it to meet and maintain the specified accuracy. It relates primarily to vertical comparators, but may be adopted for horizontal comparators in so far as the requirements are applicable.

In addition to stating requirements for parts such as work-table, measuring anvil, pointer, scale, &c., standards of performance are laid down and tolerances on scale readings are specified in inches and millimetres for comparators of various degrees of sensitivity within the ranges covered by the standard.

Catalogues

J. H. SANKEY AND SON, Ltd., Refractories Works, Ilford, Essex.—Leaflet describing Sankey's acid-resisting cement.

SIEMENS ELECTRIC LAMPS AND SUPPLIES, Ltd., 38 and 39, Upper Thames Street, London, E.C.4.—Leaflet illustrating and describing the Siemens "Safetrip" earth leakage switch socket for sub-circuit protection.

STANDARD TELEPHONES AND CABLES, Ltd., Warwick Road, Boreham Wood, Herts.—Advance information leaflet F/G1, giving details of germanium junction photo-electric cells and power rectifiers. Leaflet F/APL.1, giving details of the germanium junction photo-electric cell type P50A.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

DIESEL ENGINE USERS ASSOCIATION

Thurs., Oct. 21st.—Caxton Hall, Westminster, London, S.W.1, Presidential Address, "Modern Diesel Tugs," F. J. Mayor, 2.30 p.m.

HULL CHEMICAL AND ENGINEERING SOCIETY

Tues., Oct. 26th.—Church Institute, Hull, "Planned Maintenance," W. Jones, 7.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

Tues., Oct. 19th.—LIVERPOOL CENTRE: Liverpool Engineering Society, 9, The Temple, 24, Dale Street, Liverpool, Chairman's Address, G. W. A. Illingworth, 6.30 p.m.

Wed., Oct. 20th.—N. LANCASHIRE GROUP: Demonstration Theatre, N.W. Electricity Board, 19, Friargate, Preston, Presidential Address, E. C. Lennox, 7.15 p.m.——TEES-SIDE GROUP: Cleveland Scientific and Technical Institute, Corporation Road, Middlesbrough, "Sports Lighting," M. W. Peirce, 6.30 p.m.

Fri., Oct. 22nd.—BATH AND BRISTOL CENTRE: Royal Hotel, Bristol, "An Analytical Approach to Industrial Lighting," W. Imrie Smith, 6.15 p.m.

Mon., Oct. 25th.—LEEDS CENTRE: E.L.M.A. Lighting Service Bureau, 24, Aire Street, Leeds, 1, Chairman's Address, J. R. Bardsley; Presidential Address, E. C. Lennox, 6.15 p.m.——LEICESTER CENTRE: Demonstration Theatre, E. Midlands Electricity Board, Charles Street, Leicester, "Artificial Illumination of Horticultural Crops," A. Calvert, 6 p.m.

Fri., Oct. 29th.—BIRMINGHAM CENTRE: James Watt Memorial Institute, Great Charles Street, Birmingham, "Teaching Illuminating Engineering," 6.30 p.m.

INCORPORATED PLANT ENGINEERS

To-day, Oct. 15th.—BIRMINGHAM BRANCH: Imperial Hotel, Temple Street, Birmingham, Mobile Plant Discussion Group, "Caterpillar Tractors," Film and Discussion, 7.30 p.m.

Mon., Oct. 18th.—MERSEYSIDE AND N. WALES BRANCH: Radiant House, Bold Street, Liverpool, "Repair of Cracked Castings," N. Tinwell, 7.15 p.m.

Tues., Oct. 19th.—S. WALES BRANCH: Mackworth Hotel, Swansea, "Power Factor in Industry," W. P. Warren, 7.15 p.m.

Wed., Oct. 20th.—GLASGOW BRANCH: Scottish Building Centre, 425–427, Sauchiehall Street, Glasgow, "Gas Turbines," A.W. Vickers, 7 p.m.——KENT BRANCH: Bull Hotel, Rochester, "Recent Research in Pressure Vessels," P. H. R. Lane, 7 p.m.——WESTERN BRANCH: Grand Hotel, Bristol, "Interplanetary Flight," J. Humphries, 7.15 p.m.

Thurs., Oct. 21st.—BLACKBURN BRANCH: Golden Lion Hotel, Blackburn, "Trade Effluents and Sewage Disposal," G. Ainsworth, 7.30 p.m.——LONDON BRANCH: All-Day Visit to the Oil Refineries at Shell Haven, Shell-Mex and B.P., Ltd.

Tues., Oct. 26th.—SOUTHAMPTON BRANCH: Evening Visit (with special reference to costing) to Folland Aircraft, Ltd., Hamble, 5.30 p.m.——W. AND E. YORKS BRANCH: The University, Leeds, "Heatless Repair of Broken Castings," 7.30 p.m.

Thurs., Oct. 28th.—SHEFFIELD AND DISTRICT BRANCH: Grand Hotel, Sheffield, "Boiler Feed Water Treatment for Industrial Problems," C. J. Carter, 7.30 p.m.

Fri., Oct. 29th.—BIRMINGHAM BRANCH: Imperial Hotel, Temple Street, Birmingham, Films, "Oil in Industry," "Liquid Fuel in Industry," "Grease," "Project 074," followed by discussion, 7.30 p.m.

INSTITUTE OF INDUSTRIAL SUPERVISORS

Thurs., Oct. 21st.—S.E. LONDON SECTION: Woolwich Polytechnic, Woolwich, S.E.18, "Money in Industry," G. H. Bairstow, 7.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Thurs., Oct. 21st.—N.E. COAST SECTION: Stephenson Building, King's College, Claremont Road, Newcastle upon Tyne, "Some Fuel Injection Problems," W. P. Mansfield, 6.15 p.m.

INSTITUTE OF METALS

Mon., Oct. 18th.—SHEFFIELD LOCAL SECTION: University Buildings, St. George's Square, Sheffield, "Metallurgical Problems of Atomic Energy," L. Rotherham, 7.30 p.m.

INSTITUTE OF PETROLEUM

Wed., Oct. 20th.—Chemical Society, Burlington House, Piccadilly, London, W.1, "Platforming," Dr. Gustav Egloff, 5.30 p.m.

Thurs. and Fri., Oct. 28th and 29th.—Institution of Electrical Engineers, Savoy Place, London, W.C.2, Conference on "Molecular Spectroscopy," organised by Spectroscopic Panel of the Hydrocarbon Research Group.

INSTITUTE OF REFRIGERATION

Thurs., Oct. 21st.—Science Museum, South Kensington, London S.W.7, "The Properties of Metals at Low Temperatures," N. P. Allen, 5.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Thurs., Oct. 21st.—WESTERN CENTRE: Rougemont Hotel, Exeter, "Lubrication and Greases for Road Transport Vehicles," E. M. Dodds, 7.30 p.m.——LONDON CENTRE: Royal Society of Arts, John Adam Street, London, W.C.2, "Ball and Roller Bearings: Their Treatment and Repair," M. J. Knaggs, 6.30 p.m.——YORKSHIRE CENTRE: Hotel Metropole, King Street, Leeds, 1, Technical Film, "Fuel Equipment," followed by a paper, "Fuel Equipment Maintenance," A. Charlesworth, 7.30 p.m.

Tues., Oct. 26th.—N. EASTERN GROUP: Royal County Hotel, Durham, "Protective Finishes for Road Vehicles," W. T. Watson, 7 p.m.

INSTITUTE OF WELDING

Tues., Oct. 19th.—LIVERPOOL AND DISTRICT BRANCH: College of Technology, Byron Street, Liverpool, "Oxygen in Industry and Gas Welding Repairs in Light Engineering," F. D. Hucklesby, 7.15 p.m.

Wed. to Fri., Oct. 27th to 29th.—AUTUMN MEETING in London.

INSTITUTION OF CHEMICAL ENGINEERS

To-day, Oct. 15th.—LONDON GRADUATES' AND STUDENTS' SECTION: Caxton Hall, London, S.W.1, "Steam Jet Refrigeration," G. C. Betts, 6.30 p.m.

INSTITUTION OF CIVIL ENGINEERS

Mon., Oct. 18th.—HYDRAULICS MEETING: Great George Street, Westminster, London, S.W.1, "Model Experiments on the Storm Surge of 1953 in the Thames Estuary and the Reduction of Future Surges," F. H. Allen, W. A. Price and Sir Claude Inglis, 5.30 p.m.

Tues., Oct. 26th.—MARITIME MEETING: Great George Street, Westminster, London, S.W.1, "The Queen Elizabeth II Dock," D. C. Milne, 5.30 p.m.

Tues., Nov. 2nd.—Great George Street, Westminster, London, S.W.1, Presidential Address, D. M. Watson, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., Oct. 18th.—INFORMAL MEETING: Savoy Place, London, W.C.2, Discussion on "Electricity in the Future," opened by the President, 5.30 p.m.

Tues., Oct. 19th.—MEASUREMENTS SECTION: Savoy Place, London, W.C.2, Chairman's Address, M. Whitehead, 5.30 p.m.——N. MIDLAND CENTRE: British Electricity Authority, 1, Whitehall Road, Leeds, 1, "Electricity in the Wool Textile Industry," A. J. Francis and T. H. Carr, 6.30 p.m.——S.E. SCOTLAND SUB-CENTRE: Carlton Hotel, North Bridge, Edinburgh, "An Analogue Computer for Use in the Design of Servo-Mechanisms," E. E. Ward, 7 p.m.——LONDON STUDENTS' SECTION: Public Library, Chelmsford, Chairman's Address, "The History of the Institution," M. C. Cubitt, 7 p.m.

Thurs., Oct. 21st.—UTILISATION SECTION: Savoy Place, London, W.C.2, Chairman's Address, J. I. Bernard, 5.30 p.m.

Mon., Oct. 25th.—RADIO SECTION: Savoy Place, London, W.C.2, Discussion on "Whether Compatibility is Necessary for a Colour Television System in Great Britain," opened by E. P. Wethey, 5.30 p.m.

Tues., Oct. 26th.—LONDON STUDENTS' SECTION: R.E.M.E. Training Centre, Hazebrouck Barracks, Arborfield, Berks, Chairman's Address, "The History of the Institution," M. C. Cubitt, 7 p.m.

Wed., Oct. 27th.—SUPPLY SECTION: Savoy Place, London, W.C.2, Chairman's Address, J. D. Peattie, 5.30 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., Oct. 19th.—39, Elmbank Crescent, Glasgow, "Recent Developments in the Application of Machine Tools," J. R. Young, 7.30 p.m.

Tues., Nov. 2nd.—39, Elmbank Crescent, Glasgow, "Resistance and Propulsion of Single-Screw Coasters Part II, L/B-6," J. Dawson, 7.30 p.m.

INSTITUTION OF LOCOMOTIVE ENGINEERS

Wed., Oct. 20th.—GENERAL MEETING: Institution of Mechanical Engineers, 1, Birdcage Walk, London, S.W.1, "The Design of Light Alloy Coaches for East African Railways," J. F. Thring, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, Oct. 15th.—GENERAL MEETING, 1, Birdcage Walk, Westminster, London, S.W.1, Presidential Address, R. W. Bailey, 5.30 p.m.

Mon., Oct. 18th.—LUTON A.D. CENTRE: Town Hall, Luton, "A Survey of Fifty Years of Transmission Development," T. C. F. Stott, 7.30 p.m.

Tues., Oct. 19th.—STEAM GROUP DISCUSSION: 1, Birdcage Walk, Westminster, London, S.W.1, "Measurement of the Wetness of Steam," 6.45 p.m.——E. MIDLANDS GRADUATES' SECTION: Gas Showrooms, Peterborough, "Training Within Industry," W. Ward, 7.15 p.m.

Wed., Oct. 20th.—N.E. A.D. CENTRE: Chemistry Lecture Theatre, The University, Leeds, "Heat Losses in I.C. Engines," Arthur Leah, 7.30 p.m.——SOUTHERN GRADUATES' SECTION: Municipal College, Portsmouth, Chairman's Address, "The Modern Sports Car," J. Frankham, 7 p.m.

Thurs., Oct. 21st.—MIDLAND BRANCH: James Watt Memorial Institute, Great Charles Street, Birmingham, "The Development and Scope of Work Study," R. M. Currie, 6 p.m.——N.W. INDUSTRIAL ADMINISTRATION AND ENGINEERING PRODUCTION GROUP: Engineers' Club, Albert Square, Manchester, "Copying Devices and Tracer-Controlled Machine Tools," H. C. Town, 6.45 p.m.——N.W. A.D. CENTRE: Crewe Arms Hotel, Crewe, "Brakes for High-Speed Automobiles," J. A. Channer, 7.15 p.m.

Fri., Oct. 22nd.—GENERAL MEETING, HYDRAULICS GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, "Modern Development in the Use of Large Single-Entry Centrifugal Pumps," H. H. Anderson, 5.30 p.m.

Mon., Oct. 25th.—SCOTTISH A.D. CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Engine Research and Development as a Service to Industry: A Personal Experience," J. H. Pitchford, 7.30 p.m.

INSTITUTION OF MINING AND METALLURGY

Thurs., Oct. 21st.—GENERAL MEETING: Geological Society, Burlington House, Piccadilly, London, W.1, Discussion of the Papers, "The Effect of Surface Films on the Polarising Angles of Pyrite, Coal and Fluorspar," P. F. Whelan and R. P. Wilkinson; "Flotation of Quartz and Felspar by Dodecylamine," M. H. Buckenham and J. Rogers, 5 p.m.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Wed., Oct. 27th.—INFORMAL MEETING: Conference Room, 4th Floor, Waterloo Bridge House, London, S.E.1, Vice-Chairman's Address, "Is Your Stores Problem Really Necessary?" F. C. G. Greening, 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Mon., Oct. 18th.—MANCHESTER SECTION: Reynolds Hall, College of Technology, Sackville Street, Manchester, 1, "Tracer Control of Machine Tools," J. Lund, 7.15 p.m.——DERBY SECTION: College of Art, Green Lane, Derby, "The Use of the Autocollimator in Engineering Metrology," C. C. Taylerson, 7 p.m.——STOKE-ON-TRENT SECTION: Town Hall, Hanley, Stoke-on-Trent, "Engineering Potentialities of Spheroidal Graphite Cast Iron," A. B. Everett, 7.15 p.m.

Tues., Oct. 19th.—COVENTRY SECTION: Craven Arms, High Street, Coventry, "The Application of Hydraulic Power as an Aid to Productivity versus Electronics," F. B. Levetus and R. H. Kelsall, 7 p.m.——LONDON GRADUATES' SECTION: 10, Chesterfield Street, London, W.1, "Ultrasonic Machining of Hard Materials," C. F. Brockelsby, 7.15 p.m.

Wed., Oct. 20th.—BIRMINGHAM SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, "A Job Evaluation System and its Influence on Productivity," R. N. Marland, 7 p.m.——CORNWALL SECTION: Technical College, Treventon, Pool, Redruth, Cornwall, Film Evening, 7.15 p.m.——NORWICH SECTION: Esplanade Restaurant, Lowestoft, "Arc Welding in Engineering and Ship Work," H. Roscoe and R. A. Peacock, 7.30 p.m.——WOLVERHAMPTON GRADUATE SECTION: Technical College, Wulfruna Street, Wolverhampton, "Safety in the Factory," E. W. Huddy, 7.30 p.m.

Thurs., Oct. 21st.—GLASGOW SECTION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Ball and Roller Bearing Manufacture and Application," C. S. Clarke, 7.30 p.m.——LONDON SECTION: Royal Empire Society, Northumberland Avenue, London, W.C.2, "A Production Engineer Reviews Welding Shop Organisation and the Relationship of the Welding Shop to Other Manufacturing Departments," F. G. C. Sandiford, 7 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

To-day, Oct. 15th.—LANCASHIRE AND CHESHIRE BRANCH: Walker Art Gallery, Liverpool, Chairman's Address, W. D. Blades, Films, "Soils and Foundations," and "Loch Sloy," 7.15 p.m.

Tues., Oct. 19th.—LONDON GRADUATES' AND STUDENTS' SECTION: 11, Upper Belgrave Street, London, S.W.1, "Government Offices, Whitehall Gardens, the Special Problem of the Resiting of a Historic Building," L. Scott White, 5.55 p.m.——WALES AND MONMOUTHSHIRE BRANCH: S. Wales Institute of Engineers, Park Place, Cardiff, "Llandarcy Refining Expansion Engineering," F. V. M. Bell, 6.30 p.m.

Fri., Oct. 22nd.—MIDLAND COUNTIES BRANCH: James Watt Memorial Institute, Great Charles Street, Birmingham, Chairman's Address, W. Phillips, 6 p.m.

Mon., Oct. 25th.—SCOTTISH BRANCH: Cadoro Restaurant, Union Street, Glasgow, Chairman's Address, W. Heigh, 6 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Oct. 15th.—INFORMAL MEETING: Pepys House, 14, Rochester Row, London, S.W.1, "Problems Relating to Meter and Instrument Bearings," G. F. Shotter, 7 p.m.

Fri., Oct. 22nd.—INFORMAL MEETING: Pepys House, 14, Rochester Row, London, S.W.1, "The Manufacture of Portland Cement," W. C. Flitton, 7 p.m.

Fri., Oct. 29th.—INFORMAL MEETING: Pepys House, 14, Rochester Row, London, S.W.1, "Some Notes on the Static Compressive Strength of Wool Felt, with Reference to the Isolation of Shock," followed by "Some Notes on the Dynamic Characteristics of Wool Felt," R. J. Herbert, 7 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

To-day, Oct. 15th.—Engineers' Club, Albert Square, Manchester, "Metals: Their Use and Testing," L. E. Benson, 6.45 p.m.

Fri., Oct. 29th.—Engineers' Club, Albert Square, Manchester, "Testing Lubricants for the Prevention or Promotion of Wear," T. B. Lane, 6.45 p.m.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

To-day, Oct. 15th.—Lecture Theatre, Literary and Philosophical Society, Newcastle upon Tyne, Presidential Address, P. L. Jones, 6.15 p.m.

REINFORCED CONCRETE ASSOCIATION

Wed., Oct. 20th.—11, Upper Belgrave Street, London, S.W.1, "The Use of Reinforced Concrete in the Gas Industry," S. V. Gardner, 6 p.m.

ROYAL AERONAUTICAL SOCIETY

Tues., Oct. 19th.—GRADUATES' AND STUDENTS' SECTION: 4, Hamilton Place, London, W.1, "The Propeller-Turbine in Airline Service," T. M. Corson, 7.30 p.m.

Thurs., Oct. 21st.—MAIN LECTURE: Institution of Mechanical Engineers, 1, Birdcage Walk, Westminster, London, S.W.1, "The Development of Re-heat," J. L. Edwards, 6 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Mon., Oct. 18th.—GENERAL MEETING: 12, Great George Street, London, S.W.1, "Practical Aspects of the Housing Repairs and Rents Act, 1954," F. W. J. Adams, 5.30 p.m.

Wed., Oct. 20th.—QUANTITY SURVEYORS' GENERAL MEETING: 12, Great George Street, London, S.W.1, Discussion on "Specifications and Bills of Quantities: Their Use and Interrelation," opened by A. R. F. Anderson, J. A. Burrell and D. E. Woodbine Parish, 6 p.m.

ROYAL METEOROLOGICAL SOCIETY

Wed., Oct. 20th.—49, Cromwell Road, South Kensington, London, S.W.7, "The Partition and Intensity of Eddy Energy at the 91m Level during Unstable Conditions," R. A. McCormick; "Turbulence in the Upper Air," F. J. Scrase; "Five Flights Through a Thunderstorm Belt," R. F. Jones, 5 p.m.

ROYAL SANITARY INSTITUTE

To-day, Oct. 15th.—SESSIONAL MEETING: Technical College Hall, Barnsley, "The Handicapped and the Community: Some Suggestions," G. A. W. Neill; "The Re-Location of Population and its Problems," S. P. Thompson, 10 a.m.

SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS

Mon., Oct. 18th.—University Building, St. George's Square, Sheffield, "Metallurgical Problems of Atomic Energy," L. Rotherham, 7.30 p.m.

SOCIETY OF CHEMICAL INDUSTRY

Tues., Oct. 19th.—Geological Society, Burlington House, Piccadilly, London, W.1, Film, "Corrosion in Action," 5.30 p.m.

Thurs., Oct. 21st.—ROAD AND BUILDING MATERIALS GROUP: Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1, "Manufacture and Applications of Glass in the Building Industry," P. M. Davidson, 6 p.m.

WOMEN'S ENGINEERING SOCIETY

Mon., Oct. 25th.—LONDON BRANCH: 35, Grosvenor Place, London, S.W.1, "The Metal Spraying Process," J. A. Shepherd, 7 p.m.